Application Note No. 142
Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-Hardened BFP540ESD RF Transistor draws 3 mA
LEGAL DISCLAIMER

THE INFORMATION GIVEN IN THIS APPLICATION NOTE IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office (www.infineon.com).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office.

Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.
<table>
<thead>
<tr>
<th>Page</th>
<th>Subjects (major changes since last revision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Small changes in figure descriptions</td>
</tr>
</tbody>
</table>
1 Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-Hardened BFP540ESD RF Transistor draws 3 mA

Applications

Overview
The ESD-hardened BFP540ESD RF Transistor, capable of sustaining 1000 V Electro Static Discharge (ESD) pulses per the Human Body Model (HBM) is unique in terms of combining high RF performance with ESD-robustness:
- Transit frequency \( f_T = 34 \) GHz
- Maximum Stable Gain MSG of 21 dB @ 1.8 GHz
- Minimum Noise Figure \( F_{\text{min}} = 0.9 \) dB @ 1.8 GHz

Features
- Low current: 3.3 mA @ 5 V; 3 V operation possible with resistor value change
- Low Noise Figure: 1.5 dB Noise figure at 315 / 434 MHz
- Gain: 14.6 dB @ 315 MHz
- Low cost design on 2-layer FR4 PCB material with no chip coils; total parts count = 10; PCB area \( \approx 50 \) mm²
- Unconditionally Stable: \( K>1, B_1>0 \) from 5 MHz to 6 GHz

BFP540ESD is shown in a low cost, low current (3 mA) broadband resistive-feedback UHF LNA. The amplifier runs from a 5 V supply, but could use 3 V with simple resistor value changes. Broadband design permits use of the LNA from < 100 MHz to > 1 GHz with no component changes required, and the good input / output match over this entire frequency range eases integration with other system blocks, e.g. bandpass filters. Only resistors and capacitors are required (0402 case size). PCB area 50 = mm². Please refer to schematic diagram (Figure 2). A PCB originally designed for the smaller TSFP-4 package was employed for this demo; so the larger SOT343 package used by the BFP540ESD was made to fit the PCB footprint as well as possible.

Summary of Results
\( T = 25 \) °C, network analyzer source power = -30 dBm, \( V_{\text{CC}} = 5.0 \) V, \( I = 3.3 \) mA, \( z = 50 \) Ω

Table 1 Summary of Results

<table>
<thead>
<tr>
<th>Frequency</th>
<th>dB[s11]²</th>
<th>dB[s12]²</th>
<th>dB[s21]²</th>
<th>dB[s22]²</th>
<th>NF* dB</th>
<th>IIP² dBm</th>
<th>OIP² dBm</th>
<th>IIP1dB dBm</th>
<th>OIP1dB dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>11.2</td>
<td>15.0</td>
<td>21.0</td>
<td>15.2</td>
<td>1.5</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>315</td>
<td>11.2</td>
<td>14.6</td>
<td>21.1</td>
<td>14.5</td>
<td>1.5</td>
<td>-13.2</td>
<td>+1.5</td>
<td>-21.5</td>
<td>-7.9</td>
</tr>
<tr>
<td>390</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.5</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>434</td>
<td>11.4</td>
<td>14.2</td>
<td>21.3</td>
<td>13.8</td>
<td>1.5</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>915</td>
<td>11.9</td>
<td>12.1</td>
<td>21.4</td>
<td>11.8</td>
<td>1.6</td>
<td>---</td>
<td>---</td>
<td>-19.6</td>
<td>-8.5</td>
</tr>
</tbody>
</table>

* Note that PCB loss is not extracted. If PCB loss were extracted, NF would be 0.1 to 0.2 dB lower.
PCB Cross Sectional Diagram

Note standard low-cost FR4 material is used

Figure 1  PCB - Cross Sectional Diagram

Schematic Diagram

Figure 2  Schematic Diagram
Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-

Noise Figure, Plot, 100 MHz to 950 MHz, Center of Plot (x-axis) is 525 MHz.

Rohde & Schwarz FSEK3

Noise Figure

| EUT Name: | BFP540ESD Wideband Feedback LNA |
| Manufacturer: | Infineon Technologies |
| Operating Conditions: | V = 5.0 V, I = 3.3 mA, T = 25 C |
| Operator Name: | Gerard Wevers |
| Test Specification: | 900 MHz ISM |
| Comment: | on PCB 540F-041503 Rev A |
| 9 March 2006 |

Analyzer

RF Att: 0.00 dB  
RBW: 1 MHz  
Range: 40.00 dB

Ref Lvl: -40.00 dBm  
VBW: 100 Hz  
Ref Lvl auto: ON

Measurement

2nd stage corr: ON  
Mode: Direct  
ENR: HP346AN

Figure 3  Noise Figure

AN142_plot_nf.vsd
## Noise Figure, Tabular Data

From Rohde & Schwarz FSEM30 + FSEK3  
Preamplifier = MITEQ SMC-02

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Noise Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 MHz</td>
<td>1.48 dB</td>
</tr>
<tr>
<td>125 MHz</td>
<td>1.46 dB</td>
</tr>
<tr>
<td>150 MHz</td>
<td>1.42 dB</td>
</tr>
<tr>
<td>175 MHz</td>
<td>1.37 dB</td>
</tr>
<tr>
<td>200 MHz</td>
<td>1.43 dB</td>
</tr>
<tr>
<td>225 MHz</td>
<td>1.45 dB</td>
</tr>
<tr>
<td>250 MHz</td>
<td>1.46 dB</td>
</tr>
<tr>
<td>275 MHz</td>
<td>1.47 dB</td>
</tr>
<tr>
<td>300 MHz</td>
<td>1.48 dB</td>
</tr>
<tr>
<td>325 MHz</td>
<td>1.49 dB</td>
</tr>
<tr>
<td>350 MHz</td>
<td>1.46 dB</td>
</tr>
<tr>
<td>375 MHz</td>
<td>1.50 dB</td>
</tr>
<tr>
<td>400 MHz</td>
<td>1.47 dB</td>
</tr>
<tr>
<td>425 MHz</td>
<td>1.48 dB</td>
</tr>
<tr>
<td>450 MHz</td>
<td>1.48 dB</td>
</tr>
<tr>
<td>475 MHz</td>
<td>1.50 dB</td>
</tr>
<tr>
<td>500 MHz</td>
<td>1.52 dB</td>
</tr>
<tr>
<td>525 MHz</td>
<td>1.53 dB</td>
</tr>
<tr>
<td>550 MHz</td>
<td>1.52 dB</td>
</tr>
<tr>
<td>575 MHz</td>
<td>1.50 dB</td>
</tr>
<tr>
<td>600 MHz</td>
<td>1.53 dB</td>
</tr>
<tr>
<td>625 MHz</td>
<td>1.52 dB</td>
</tr>
<tr>
<td>650 MHz</td>
<td>1.52 dB</td>
</tr>
<tr>
<td>675 MHz</td>
<td>1.53 dB</td>
</tr>
<tr>
<td>700 MHz</td>
<td>1.51 dB</td>
</tr>
<tr>
<td>725 MHz</td>
<td>1.53 dB</td>
</tr>
<tr>
<td>750 MHz</td>
<td>1.54 dB</td>
</tr>
<tr>
<td>775 MHz</td>
<td>1.53 dB</td>
</tr>
<tr>
<td>800 MHz</td>
<td>1.55 dB</td>
</tr>
<tr>
<td>825 MHz</td>
<td>1.55 dB</td>
</tr>
<tr>
<td>850 MHz</td>
<td>1.57 dB</td>
</tr>
<tr>
<td>875 MHz</td>
<td>1.59 dB</td>
</tr>
<tr>
<td>900 MHz</td>
<td>1.58 dB</td>
</tr>
<tr>
<td>925 MHz</td>
<td>1.63 dB</td>
</tr>
<tr>
<td>950 MHz</td>
<td>1.62 dB</td>
</tr>
</tbody>
</table>
Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-

Scanned Image of PC Board

Figure 4 Image of PC Board
Scanned Image of PC Board, Close-In Shot.

Note BFP540ESD in SOT343 package is kloodged into PCB footprint originally designed for smaller TSFP-4 package.
Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-Gain Compression Test, 315 MHz

Amplifier is checked for 1 dB compression point at $V_{CC} = 5.0 \text{ V}$, $I_C = 3.3 \text{ mA}$, $T = 25 ^\circ \text{C}$). An Agilent power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in "Power Sweep" mode).

Input $P_{1\text{dB}} \equiv -21.5 \text{ dBm}$; Output $P_{1\text{dB}} = -21.5 \text{ dBm} + (\text{Gain} - 1 \text{ dB}) = -21.5 \text{ dBm} + 13.6 \text{ dB} = -7.9 \text{ dBm}$

<table>
<thead>
<tr>
<th>$P_{\text{OUT}}, \text{ dBm}$</th>
<th>Gain, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>-33</td>
<td>14.6</td>
</tr>
<tr>
<td>-32</td>
<td>14.6</td>
</tr>
<tr>
<td>-31</td>
<td>14.6</td>
</tr>
<tr>
<td>-30</td>
<td>14.6</td>
</tr>
<tr>
<td>-29</td>
<td>14.5</td>
</tr>
<tr>
<td>-28</td>
<td>14.5</td>
</tr>
<tr>
<td>-27</td>
<td>14.4</td>
</tr>
<tr>
<td>-26</td>
<td>14.3</td>
</tr>
<tr>
<td>-25</td>
<td>14.2</td>
</tr>
<tr>
<td>-24</td>
<td>14.1</td>
</tr>
<tr>
<td>-23</td>
<td>13.9</td>
</tr>
<tr>
<td>-22</td>
<td>13.7</td>
</tr>
<tr>
<td>-21</td>
<td>13.5</td>
</tr>
<tr>
<td>-20</td>
<td>13.2</td>
</tr>
<tr>
<td>-19</td>
<td>12.9</td>
</tr>
</tbody>
</table>

Figure 6 Plot of gain compression @ 315 MHz, 5 V, 3.3 mA, 25 °C
Gain Compression Test, 915 MHz

Amplifier is checked for 1 dB compression point at $V_{CC} = 5.0 \text{ V}$, $I_C = 3.3 \text{ mA}$, $T = 25 \text{ °C}$). An Agilent power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in "Power Sweep" mode).

Input $P_{1\text{dB}} \equiv -19.6 \text{ dBm}$; Output $P_{1\text{dB}} = -19.6 \text{ dBm} + (\text{Gain} - 1 \text{ dB}) = -19.6 \text{ dBm} + 11.1 \text{ dB} = -8.5 \text{ dBm}$

Table 4  Gain Compression at 915 MHz

<table>
<thead>
<tr>
<th>$P_{OUT}$, dBm</th>
<th>Gain, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>-33</td>
<td>12.1</td>
</tr>
<tr>
<td>-32</td>
<td>12.1</td>
</tr>
<tr>
<td>-31</td>
<td>12.1</td>
</tr>
<tr>
<td>-30</td>
<td>12.1</td>
</tr>
<tr>
<td>-29</td>
<td>12.0</td>
</tr>
<tr>
<td>-28</td>
<td>12.0</td>
</tr>
<tr>
<td>-27</td>
<td>12.0</td>
</tr>
<tr>
<td>-26</td>
<td>11.9</td>
</tr>
<tr>
<td>-25</td>
<td>11.9</td>
</tr>
<tr>
<td>-24</td>
<td>11.8</td>
</tr>
<tr>
<td>-23</td>
<td>11.7</td>
</tr>
<tr>
<td>-22</td>
<td>11.6</td>
</tr>
<tr>
<td>-21</td>
<td>11.4</td>
</tr>
<tr>
<td>-20</td>
<td>11.2</td>
</tr>
<tr>
<td>-19</td>
<td>10.9</td>
</tr>
</tbody>
</table>

![Figure 7](AN142_plot_gain_comp_915.vsd)
Input Return Loss, Log Mag
5 MHz - 8 GHz

Figure 8  Plot of Input Return Loss
Input Return Loss, Smith Chart
Reference Plane = Input SMA RF Connector
5 MHz - 8 GHz

Figure 9  Smith Chart of Input Return Loss
Forward Gain, Wide Sweep
5 MHz - 8 GHz

Figure 10  Plot of Forward Gain
Reverse Isolation

5 MHz - 8 GHz

Figure 11  Plot of Reverse Isolation
Output Return Loss, Log Mag

5 MHz - 8 GHz

<table>
<thead>
<tr>
<th>CH1 S22</th>
<th>dB</th>
<th>MAG 10 dB/</th>
<th>REF 0 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 dB</td>
<td>1</td>
<td>GHz</td>
<td></td>
</tr>
</tbody>
</table>

-70 dB

START 5 MHz  1 GHz/ STOP 8 GHz

Date: 9.MAR.06 18:33:03

Figure 12  Plot of Output Return Loss
Output Return Loss, Smith Chart
Reference Plane = Output SMA RF Connector
5 MHz - 8 GHz

Figure 13  Smith Chart of Output Return Loss
Third Order Intercept Measurement

Input Stimulus for Amplifier Two-Tone Test:
\( f_1 = 314 \text{ MHz}, f_2 = 315 \text{ MHz}, -33 \text{ dBm each tone.} \)
(Absolute power level is verified with Agilent Power Meter, not spectrum analyzer)

LNA response to two-tone test (below).
Input \( IP_3 = -33 + (39.7 / 2) = -13.2 \text{ dBm} \)
Output \( IP_3 = -13.2 \text{ dBm} + 14.6 \text{ dB gain} = +1.5 \text{ dBm} \)

Figure 14  Tow-Tone Test, LNA Response