Low Area Dual-band LNA with Active Inductor for GSM applications

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Motivation & Application

• Different cell phone bands are used over countries
  – GSM-850: 880MHz, 25MHz bandwidth
  – GSM-1900: 1.96GHz, 60MHz bandwidth
  – Dual band LNA for device compatibility

• Inductors consume large area on analog chip
  – Bad for yield on wafer, increases unit cost
  – Try to reduce number of inductors
Design Overview

![Diagram of a circuit with GSM-850 LNA and GSM-1900 LNA connected through a switch. The diagram shows two paths for RF input and RF output, with select and enable (en) signals controlling the switch.](image-url)
1.96GHz-Band Schematic

- Two stage for isolation
- Active inductor at load
- Select = 1
**Band Selection**

Bias voltage control at LNA input  

Output gating for isolation
## Inductor Options

<table>
<thead>
<tr>
<th>Type</th>
<th>Inductance</th>
<th>Area</th>
<th>Quality Factor</th>
<th>Repeatability</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
<td>Small</td>
<td>N/A</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>On-chip spiral</td>
<td>0.2 to 50nH</td>
<td>Large</td>
<td>20</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>External discrete</td>
<td>1 to 150nH</td>
<td>Large</td>
<td>150</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>Bond-wire</td>
<td>0.5 to 5nH</td>
<td>Small</td>
<td>150</td>
<td>Poor</td>
<td>Fair</td>
</tr>
<tr>
<td>On-chip active</td>
<td>1 to 200nH</td>
<td>Small</td>
<td>0-600, tunable</td>
<td>Good</td>
<td>Poor</td>
</tr>
</tbody>
</table>

(Values for f < 2GHz)
Active Inductor Design

Active Inductor

Equivalent Circuit

\[ Z_{in} = \frac{1}{sC_{gs1}} \parallel \frac{1 + sC_{gs2}r_{o1}}{(1 + g_{m1}r_{o1})(g_{m2} + sC_{gs2})} \]

\[ L = \frac{C_{gs2}}{g_{m1}g_{m2}} \]

\[ R_s = \frac{1}{g_{m1}g_{m2}r_{o1}r_{o2}g_{m3}} \]
Active Inductor Results

\[
\begin{align*}
L &= 4.59\text{nH at 880MHz} \\
Rs &= -24.06\text{m\Omega} \\
\text{Noise voltage} &= 2.67\text{nV/}\sqrt{\text{Hz}}
\end{align*}
\]

Compensate by adding external series resistance.

Tolerable when active inductor is at LNA output.
Gain ($S_{21}$)

- Gain at GSM-850: 27.5 dB
- Gain at GSM-1900: 12.5 dB

Select = 0 and Select = 1
Noise Figure

![Graph showing noise figure across different frequencies and select settings](image)

- **NF (dB)**
  - 2.92 dB at 500 MHz (SELECT = 0)
  - 2.88 dB at 500 MHz (SELECT = 1)

- **Frequencies**
  - 500 MHz
  - 1 GHz
  - 1.5 GHz
  - 2 GHz

- **Select Settings**
  - SELECT = 0
  - SELECT = 1

- **GSM Bands**
  - GSM-850
  - GSM-1900

The graph illustrates the noise figure (NF) across different frequencies and select settings, with peaks at specific frequencies for each select option.
## Results Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Select GSM-850</th>
<th>Select GSM-1900</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center freq.</td>
<td>906.1 MHz</td>
<td>1888MHz</td>
</tr>
<tr>
<td>S11</td>
<td>-15.0dB</td>
<td>-10.69dB</td>
</tr>
<tr>
<td>S21</td>
<td>29.86dB</td>
<td>12.74dB</td>
</tr>
<tr>
<td>NF</td>
<td>2.92dB</td>
<td>2.88dB</td>
</tr>
<tr>
<td>3dB-BW</td>
<td>85.2MHz</td>
<td>905MHz</td>
</tr>
<tr>
<td>P1dB</td>
<td>-0.5dBm</td>
<td>1.995dBm</td>
</tr>
<tr>
<td>IIP3</td>
<td>-12.71dBm</td>
<td>-14.0dBm</td>
</tr>
<tr>
<td>Power</td>
<td>13.27mW</td>
<td>12.97mW</td>
</tr>
<tr>
<td>Area</td>
<td>0.301 mm²</td>
<td></td>
</tr>
</tbody>
</table>
Summary

• Switched dual band LNA for GSM 850/1900 bands is presented.

• Active inductors can replace passive inductors
  – Reduce unit cost
  – Power and noise disadvantage

• Still needs passive inductor at input port for high Q and reasonable noise figure
Questions?
References

• Thanachayanont, A.; Payne, A., "VHF CMOS integrated active inductor," *Electronics Letters*, vol.32, no.11, pp.999-1000, 23 May 1996