HIGH-Q SI-EMBEDDED
3D INDUCTORS
Air coils for power electronics

General description
A CMOS-compatible Si-embedded integrated inductor concept with high-Q factor is available to realize monolithic integration of power converters for portable electronics applications. The buried inductor is fully insulated from the Si-substrate by an oxide layer and can be manufactured with electroplated Cu. The Si-embedded spiral design suggests the highest Q-factor and integration density.

Features
- Fully CMOS-compatible
- Monolithic integration along with active electronics or silicon capacitors or as stand-alone bare die
- Easy design of inductance and Q-factor
- Core less design suitable for operation above 1MHz ($f_{res} \geq 300MHz^*$)
- Low parasitic capacitance, e.g. as low as 208fF*

Advantages
- Considerably smaller footprint compared to conventional inductors
- Higher Q-factor ($Q > 200^*$) compared to the planar RF inductors ($Q = 7^*$)
- Lower power consumption of integrated circuits ($DF = 0.0045^*$)
- No polarization losses allow for faster switching under high currents compared to ferrite-based inductors

Benefits
- High-profit due to an innovative product
- Increased market volume from expanded product options
- Reduced assembly effort by monolithic integration

* for a 1µH inductor
2 Detailed image of a high-Q planar-spiral inductor on a silicon substrate

Fig. 1 displays inductance density in terms of quality factor for solenoidal-, toroidal- and spiral-inductors. Spiral-inductors are given in planar and Si-embedded models. Number of turns in all architectures is set to be 24.

Performance Characteristics

<table>
<thead>
<tr>
<th>Technology</th>
<th>Material</th>
<th>Core</th>
<th>Area (mm$^2$)</th>
<th>Volume (mm$^3$)</th>
<th>Inductance (µH)</th>
<th>Inductance density (µH/mm$^3$)</th>
<th>Series resistance (Ω)</th>
<th>Parasitic capacitance (fF)</th>
<th>Resonance Frequency (MHz)</th>
<th>Quality factor at 5MHz</th>
<th>Dissipation factor at 5MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar-spiral on Si-surface</td>
<td>CU</td>
<td>Air core</td>
<td>19.2</td>
<td>3.92</td>
<td>1.04</td>
<td>264</td>
<td>4.23</td>
<td>174</td>
<td>375</td>
<td>7.61</td>
<td>0.13</td>
</tr>
<tr>
<td>Multi-layer inductor</td>
<td>CU</td>
<td>Ferrite core</td>
<td>1.28</td>
<td>0.64</td>
<td>1.0</td>
<td>1562</td>
<td>0.20</td>
<td>10142</td>
<td>50</td>
<td>157</td>
<td>0.006</td>
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<tr>
<td></td>
<td>CU</td>
<td>Air core</td>
<td>1.28</td>
<td>0.64</td>
<td>0.06</td>
<td>8.75</td>
<td>0.20</td>
<td>181</td>
<td>5000</td>
<td>0.88</td>
<td>1.14</td>
</tr>
<tr>
<td>Si-embedded spiral</td>
<td>CU</td>
<td>Air core</td>
<td>24.2</td>
<td>5.19</td>
<td>1.10</td>
<td>212</td>
<td>0.16</td>
<td>208</td>
<td>333</td>
<td>221</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Table 1 indicates key geometrical, technological and electrical parameters of different inductor technologies.