A 3.24-to-8.45GHz Low-Phase-Noise Mode-Switching Oscillator

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Outline

• Motivation
• Design Challenges
• Design of Mode-Switching VCO
• Measurement Results
• Conclusion
Motivation

• Cellular/WiFi frequencies from 400-to-5900MHz

• Multiple VCOs are used for multi-band
  x Area increases
  x Muxing of VCO outputs

• Need to meet stringent PN requirements
  – One-turn inductor is needed → large area
  – Coupling multiple VCOs → high power & area

• Desirable to have one VCO with
  ✓ Low PN
  ✓ Wide tuning range
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Low PN VCO Design

• Best PN from Leeson’s eq.
  – Maximize voltage swing $\rightarrow$ reliability limit
  – Maximize $Q$ of the LC tank
  – Increase Capacitance $\rightarrow$ Reduce Inductance

$ PN \downarrow \alpha \left( \frac{KT}{C} \right) \left( \frac{1}{Q} \right) V^2 $
Small Inductance Challenge

- Inductance & Q increase with area

\[ Q = \frac{L \omega}{R} \propto \frac{D^2 \omega}{D} \propto D\omega \]

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High Q & Small Inductance

- 570pH
- 288pH

Q vs Frequency (GHz)

High Q & Small Inductance

Mode Switching Inductor

Common mode voltage
No loss in switches
Mode Switching Inductor

288pH

Common mode voltage

No loss in switches

181pH

Common mode voltage

No loss in switches

Mode Switching Capacitor

$$\omega = \frac{1}{\sqrt{L_{\text{High}}(C + C_C)}}$$

$$\omega = \frac{1}{\sqrt{L_{\text{Low}}C}}$$
Mode Switching VCO

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Frequency Range

Capbank

400MHz overlap

LB Mode

HB Mode

Frequency (GHz)

3.24  4.5  4.9  8.45

Measured Phase Noise

-144.4dBc/Hz @ 10MHz→7.76GHz

-150.2dBc/Hz @ 10MHz→3.72GHz
Measured PN @ 0.8V

VCO Frequency (GHz)

PN (dBc/Hz)

100kHz
1MHz
10MHz

Figure of Merit

VCO Frequency (GHz)

FOM (dB/Hz)

100kHz
1MHz
10MHz
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Table of Comparison

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<th>This Work</th>
<th>ISSCC 2012</th>
<th>JSSCC June 2012</th>
<th>CICC 2009</th>
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</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>3.24 – 8.45 (88.7 %)</td>
<td>6.72 – 9.2 (31%)</td>
<td>2.48 – 5.62 (77.5%)</td>
<td>3.28-8.35 (87.2%)</td>
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<tr>
<td>Core Voltage (V)</td>
<td>0.8</td>
<td>1.5</td>
<td>0.6</td>
<td>1.6</td>
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<tr>
<td>Core Power (mW)</td>
<td>20</td>
<td>27</td>
<td>9.8 - 14.2</td>
<td>6.5 - 15.4</td>
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<td>Carrier (GHz)</td>
<td>3.72</td>
<td>7.76</td>
<td>3.72</td>
<td>3.72</td>
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<tr>
<td>PN (dBc/Hz) @ 100 KHz offset</td>
<td>-105.56</td>
<td>-95.25</td>
<td>-104</td>
<td>-96</td>
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<td>FoMT(dB/Hz) @ 100 KHz offset</td>
<td>202.92</td>
<td>199.05</td>
<td>191</td>
<td>195</td>
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<td>PN (dBc/Hz) @ 10 MHz offset</td>
<td>-150.22</td>
<td>-144.45</td>
<td>-151</td>
<td>-151.4</td>
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<tr>
<td>FoMT(dB/Hz) @ 10MHz offset</td>
<td>207.58</td>
<td>208.25</td>
<td>198</td>
<td>210</td>
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<td>Technology</td>
<td>40nm CMOS</td>
<td>55nm CMOS</td>
<td>65nmCMOS</td>
<td>130nm CMOS</td>
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</tbody>
</table>

Conclusions

- Dual-band mode switching oscillator demonstrated
- Wide tuning range of 3.24GHz to 8.45GHz
- Low PN of −144.4dBc/Hz @ 10MHz offset of 7.76 GHz
- High FoMT of 208.2dB/Hz @ 10MHz offset for 7.76 GHz
Acknowledgement

- TSMC University Shuttle Program
- Lorentz Solution for the EM tool
- Denny Goetz for help with testing