A 1.2V Low-Power 2.4GHz 0.18μm CMOS Quadrature VCO

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2 VCO Topology
3 Quadrature Generation
4 Bias Control
5 Capacitive Bench
6 Physical Design
7 Experimental Results
8 Conclusions
1 Introduction

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Scenario

- Very Low-Power Superheterodyne TX/RX
- PLL with Sigma-Delta Modulation
- QVCO specs:
  - Frequency BandWidth: 2.40-2.48GHz
  - Phase noise at 1Mhz: -72dBc/Hz
  - Phase noise at 2Mhz: -95dBc/Hz
  - Phase noise at 3Mhz: -105dBc/Hz
  - Quadrature 90°
  - Low-Gain < 30MHz/V
  - Very Low-Power < 1mW at 1.2V Power Supply
  - Technology: 0.18μm 1poly 6 metal 1.8V
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**VCO**

- **Ring Oscillator**
- **Relaxation Oscillator**
- **LC Oscillator**

**Avantatges:**
- Low phase noise
- One transistor Oscillators
- High frequency resonators
- High spectral purity

**Drawbacks:**
- Low Q factor
3 Quadrature Generation
Active quadrature

**Simulation Results**

- **Output Voltage** = 550 mVpp
- **Stabilization Time** = 90 ns
- **Quadrature Error** = 0.2º
- **Phase noise (3MHz)** = -120dBc/Hz
- **Harmonic difference** = 50 dB
- **Mismatch immunity** ↑

![Circuit Diagram](image_url)
DCIS’08: A 1.2V Low-Power 2.4GHz QVCO

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Double current source

Polarization control using reference follower

Modified follower

Simulation Results
5 Capacitive Bench
Switch plus Transistor

Transistor’s operation region

MIM plus Switch

CMIM↑↑
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Full-Custom Layout Design

- **Reference QVCO**
- **QVCO2 No-bias control**
- **QVCO3 Varactor**
- **QVCO4 N-Well Inductor**
- **QVCO5 Optimized Layout**
- **QVCO6 Standard Cells**
7 Experimental Results
Test bench
Reference QVCO Results

- **Power:** 700μA at 1.2V; **Freq.:** 2.45GHz

PN 3MHz
-131 dBc/Hz

Jitter ~ 2ps

I/Q Error < 1°

KVCO
20 MHz/V
Output Power

- Test bench attenuation: 5.5 dB; Buffers gain: -18 dB.

Output Voltage = 500 mVpp
Comparison with different versions

- Phase noise in QVCO2.
  - PN 3MHz -131 dBc/Hz

- Coarse Gain in QVCO3.
  - KVCO 200 MHz/V

- Phase noise in QVCO4.
  - PN 3MHz -126 dBc/Hz

- Quadrature Error in QVCO5.
  - I/Q Error < 1°
Parametric results

- Phase noise vs Current.

- Quadrature Error vs Current.

- Phase noise vs Frequency.

- Quadrature Error vs Frequency.
## State of art comparison

**Figure of Merit:**

\[
FOM = -L(\Delta f) + 20 \log \left( \frac{f_{\text{osc}}}{\Delta f} \right) - 10 \log(P_d)
\]

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Conclusions

- Great results on **phase noise**.

- **Remarkable** results in **FOM**

- **Low-current** and **Low-Power Supply**.

- Varactor vs **capacitors bench**.

- Importance of **mismatch** in **quadrature** generation.

- **Amplitude noise** appears in **very-low** amplitude **output**.

- **Effective bias control** improvement.
Thank you for your attention!!!