Lecture 13: Voltage-Controlled Oscillator-Part III
Tutorial (For more details, please refer to the LC-Oscillator tutorial on the class website)
VCO Design Issues for Narrowband Applications

- Tuning Range – need to cover all frequency channels
- Noise – impacts receiver sensitivity performance
- Power – want low power dissipation
- Isolation – want to minimize noise pathways into VCO
- Sensitivity to process/temp variations
# Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Frequency</td>
<td>2.4G</td>
<td>GHz</td>
</tr>
<tr>
<td>Tuning bandwidth</td>
<td>500</td>
<td>MHz</td>
</tr>
<tr>
<td>Ko</td>
<td>&gt;100</td>
<td>MHz/V</td>
</tr>
<tr>
<td>Phase Noise</td>
<td>&lt;-70 @ 10KHz</td>
<td>dBc/Hz</td>
</tr>
<tr>
<td>Supply</td>
<td>2.5</td>
<td>V</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>&lt;100</td>
<td>mW</td>
</tr>
</tbody>
</table>
Phase Noise as function of loaded quality factor

\[ PN = \left(\frac{f_o}{2Q\Delta f}\right)^2 \frac{F.KT}{2P_{sig}} \left(1 + \frac{f_c}{\Delta f}\right) \]

Assume
Noise Figure (F)=10dB
Architecture Choice

\[ g_{m,active} = \frac{g_{m,n} + g_{m,p}}{2} \]

\[ g_{m,active} \approx \frac{\alpha}{R_P} \]

\[ \alpha \approx 2 - 3 \]

\[ R_P = \text{Losses in the tank} \]
Varactor in LC Oscillators

- **Switched-capacitor array**
  - High tuning range
  - Discrete capacitance
  - Q depends on switches

- **PN diode**
  - Good linearity
  - High Q value

- **MOS Varactor**
  - High tuning range
  - Q depends on process technology
Varactor Implementation

![Varactor Diagram]

- Vgs
- Vg
- Bulk connected to D&S
- Vcontrol
- Vgate
- D
- S
- Vsub

Graph showing:
- C_mos vs. Vgs
- Accumulation
- Depletion
- Moderate Inversion
- Strong Inversion
- Weak Inversion

Graph illustrating the variation of C_mos with Vgs.
Tank Design
Transistor Biasing and Sizing

Equivalent Circuit Model for the VCO Core
Phase Noise Simulation (Using PSS and PNOISE)

-40.0 dBc/Hz, Relative Harmonic = 1

A: (9.9704K, -75.3042)

relative frequency (Hz)

1K 10K 100K 1M 10M

(dBc/Hz)
An Example of connection to the 50-Ohm measurement equipment [2]
1.1 GHz VCO in *JSSC’01*

- 0.35 μm CMOS technology; 2.5 V / 3.7 mA

1.1 GHz VCO in *JSSC’01*

- **Tail-biased VCO**
  - PN@3 MHz = -153 dBC/Hz

- **Top-biased VCO**
  - PN@3 MHz = -152 dBC/Hz
1.96 GHz VCO in JSSC’02

- 0.35 μm CMOS technology; 2 V / 6 mA

<table>
<thead>
<tr>
<th>Offset frequency</th>
<th>$L_y = 0$</th>
<th>$L_y = 0$</th>
<th>$L_y = 100 \text{ uF}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kHz</td>
<td>-95.5</td>
<td>-98.0</td>
<td>-105.5</td>
</tr>
<tr>
<td>600 kHz</td>
<td>-116.0</td>
<td>-120.0</td>
<td>-123.5</td>
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<tr>
<td>3 MHz</td>
<td>-131.5</td>
<td>-136.5</td>
<td>-138.5</td>
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References
