EE230-02 RFIC II
Fall 2018

Lecture 12: Oscillators

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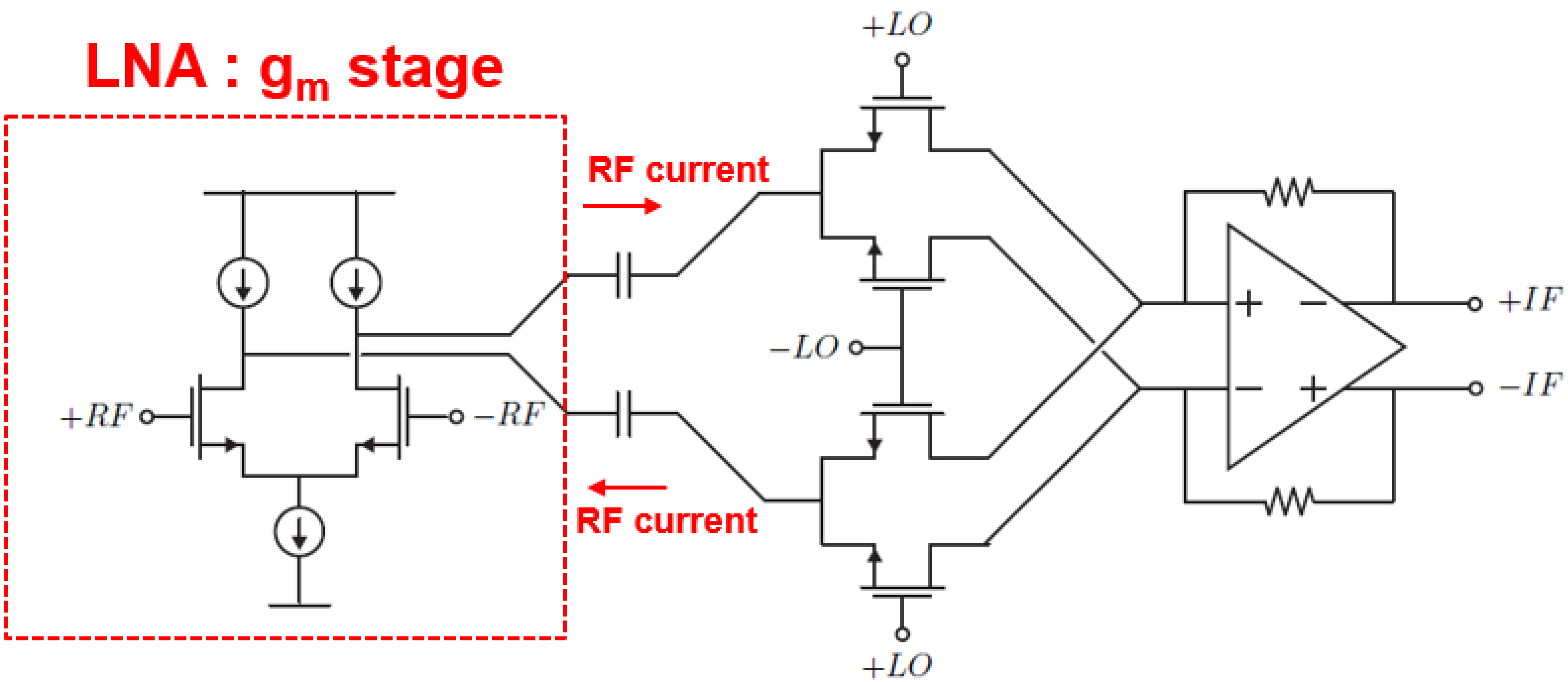
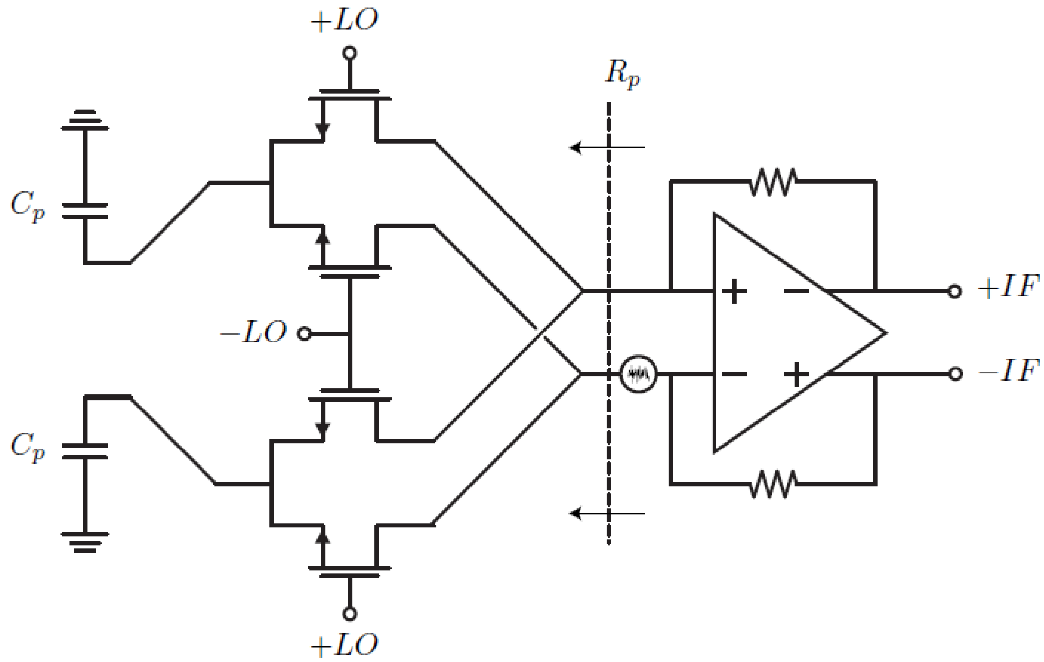
LNA + Passive Mixer

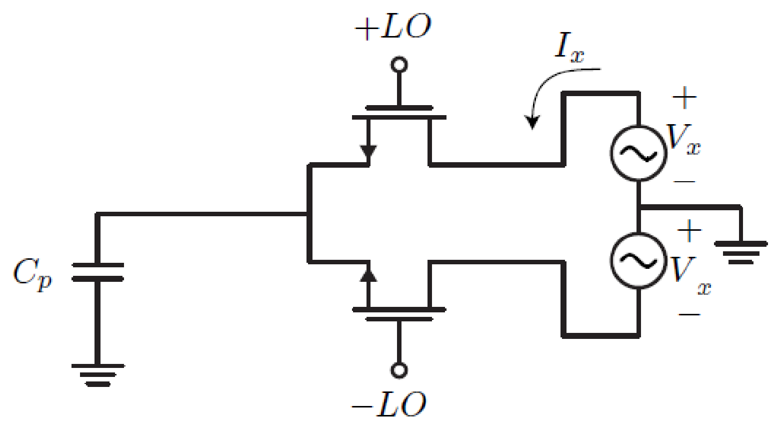


OPAMP Noise



- The op-amp input referred noise is amplified to IF. The resistance seen at the op-amp input terminals is actually a switched capacitor resistor!
- The parasitic capacitance at the output of the transconductance stage is charged and discharged at the rate of the LO.

Switched-Capacitor Resistor



- Note that the parasitic capacitances are charged at the rate of the LO to the input voltage V_x, and then to the $-V_x$, every cycle.
- The total charge transferred during a period is given by

$$Q_{tot} = C_p V_x - (-C_p V_x) = 2C_p V_x$$

- The net current is given by $I_x = \frac{Q_{tot}}{T_{LO}} = 2C_p V_x f_{LO}$

Switched-Capacitor Resistor

- Since there are two differential pairs connected to the op-amp terminals in parallel, the total charge is twice. So the effective resistance seen at this node is given by

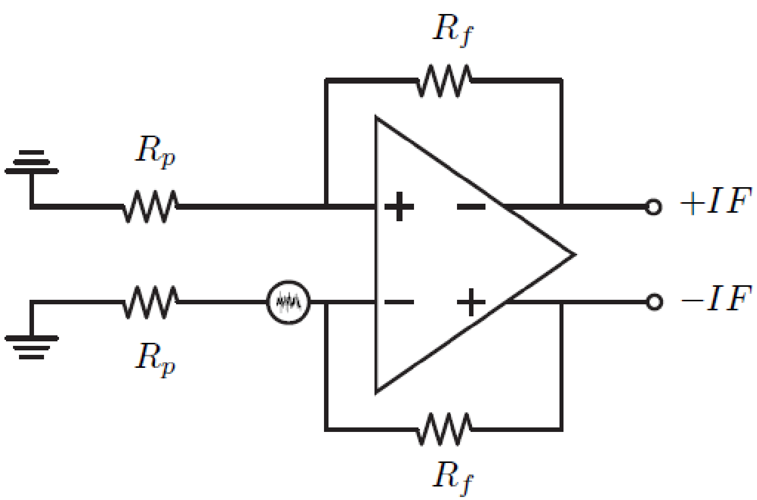
$$R_p = \frac{V_x}{2I_x}$$

- The effective resistance is therefore given by

$$R_p = \frac{1}{4f_{LO}C_p}$$

- This is a switched capacitor “resistors”.

OPAMP Noise Transfer

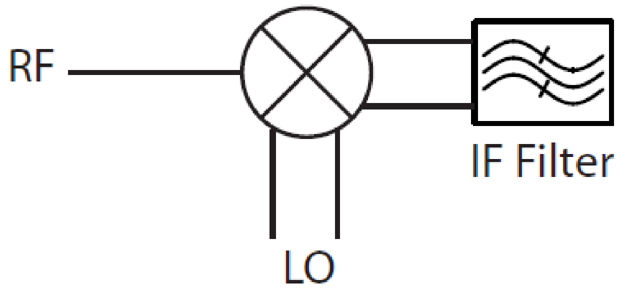


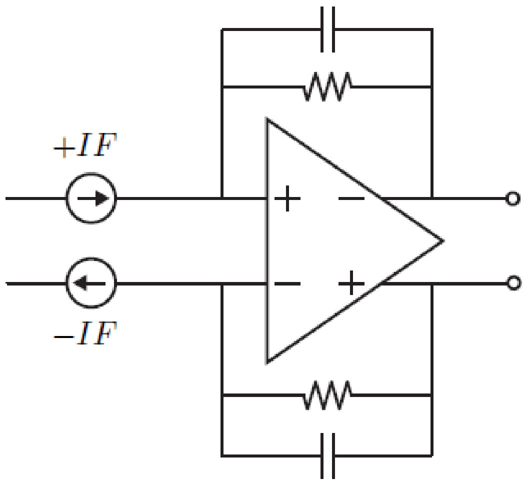
- The noise is thus transferred to the output with transfer function given by

$$\overline{v_o^2} = \left(1 + \frac{2R_f}{R_p}\right)^2 \overline{v_{amp}^2}$$

- To minimize this noise, we have to minimize the parasitic capacitance C_p and the op-amp noise.

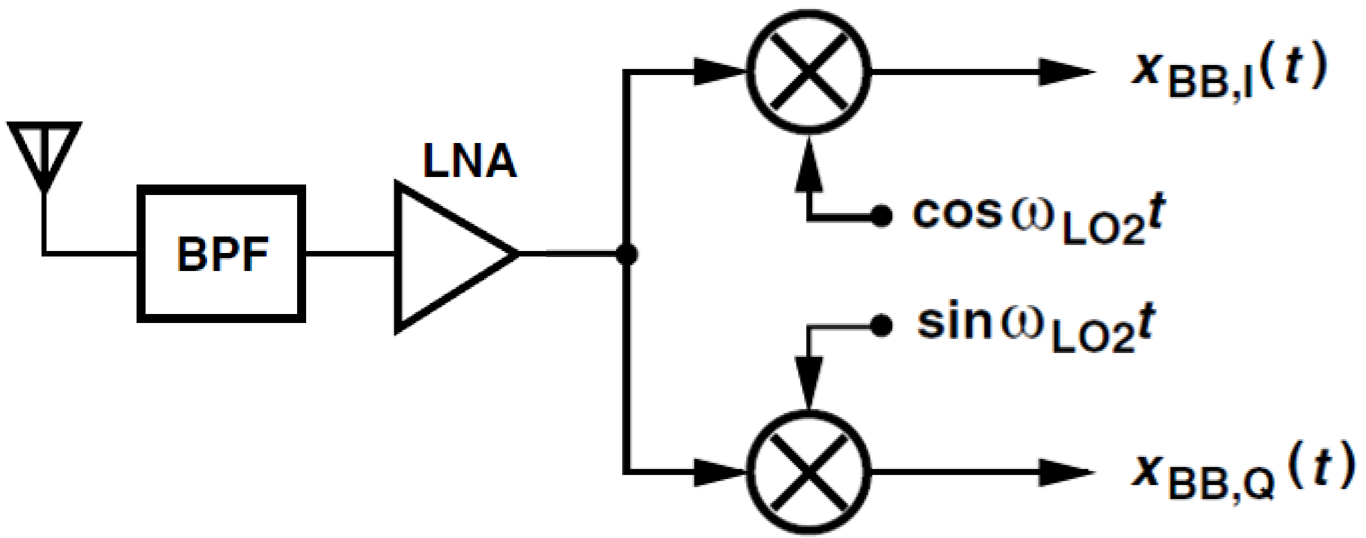
Output Filter Stage

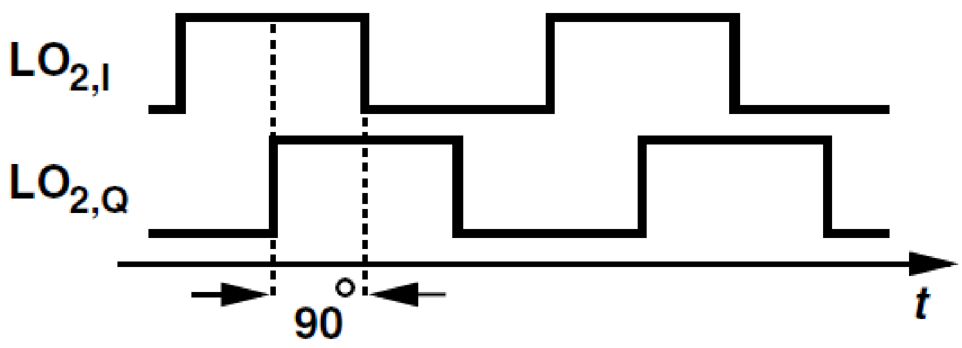




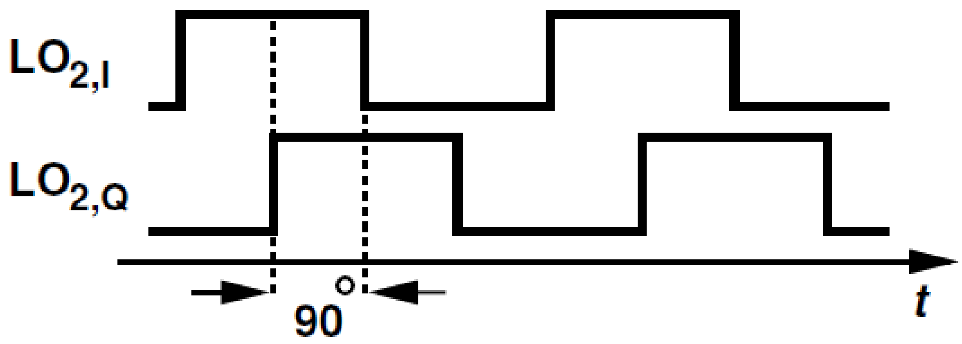
- Since a down-conversion mixer will naturally drive a filter, we see that the output current can be used directly to drive a current mode filter.
- For instance, the op-amp can be absorbed into the first stage of a multi-stage op-amp RC IF filter. The feedback resistor R_f is shunted with a capacitor C_f to produce a pole.

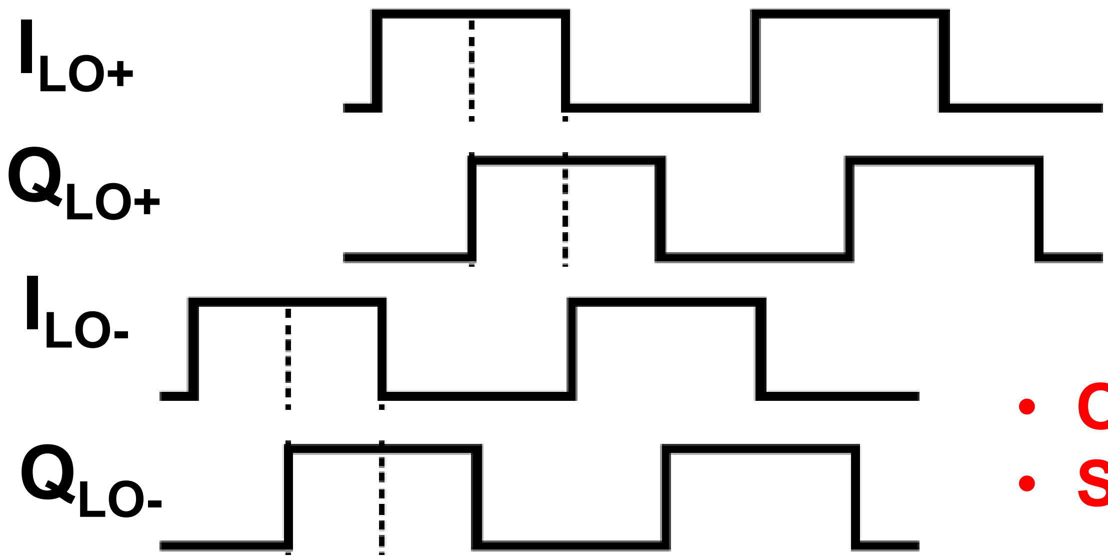
Quadrature Mixing





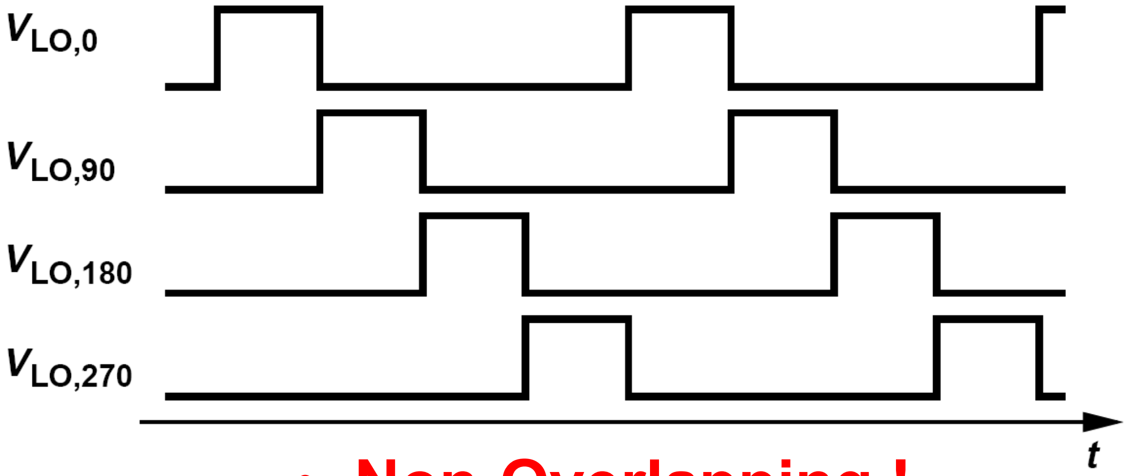
Quadrature Mixing with 50% Duty Cycle





- **Overlapping**
- **Split current to I & Q**

Quadrature Mixing with 25% Duty Cycle



- Non-Overlapping !

Pro
- 3dB more gain than 50% duty cycle

Con
- Clock generation
- Difficult to have exact 25% over PVT

Oscillators

General Principles

- ✓ Feedback View
- ✓ One-Port View
- ✓ Cross-Coupled Oscillator
- ✓ Three-Point Oscillators

Voltage-Controlled Oscillators

- ✓ Tuning Limitations
- ✓ Effect of Varactor Q
- ✓ VCOs with Wide Tuning Range

Phase Noise

- ✓ Effect of Phase Noise
- ✓ Analysis Approach I
- ✓ Analysis Approach II
- ✓ Noise of Bias Current
- ✓ VCO Design Procedure
- ✓ Low-Noise VCOs

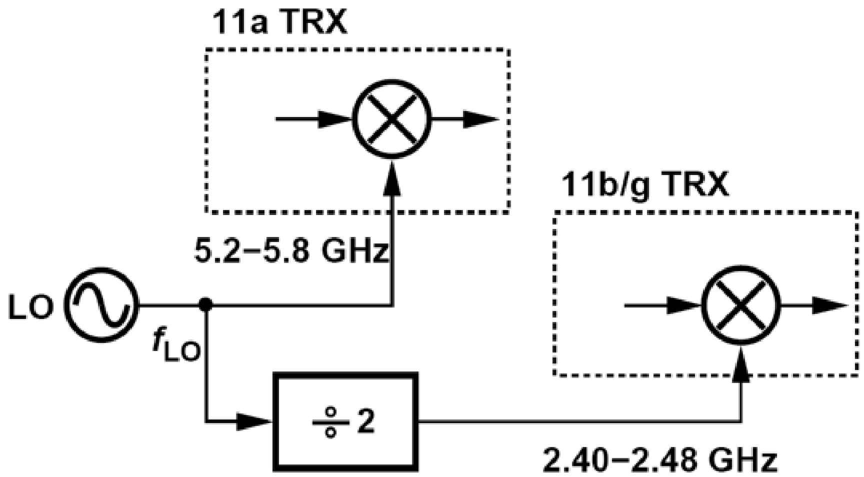
Quadrature VCOs

- ✓ Coupling into an Oscillator
- ✓ Basic Topology
- ✓ Properties of Quadrature Oscillators
- ✓ Improved Topologies

Performance Parameters: Frequency Range

- An RF oscillator Tuning Range based on two components:
  (1) The system specification;
  (2) Margin to cover PVT variations and errors due to modeling inaccuracies.

For a direct-conversion transceiver with 2.4-GHz and 5-GHz wireless bands, what is the minimum acceptable tuning range if a single LO must cover both?



Performance Parameters: Frequency Range

- An RF oscillator Tuning Range based on two components:
  (1) The system specification;
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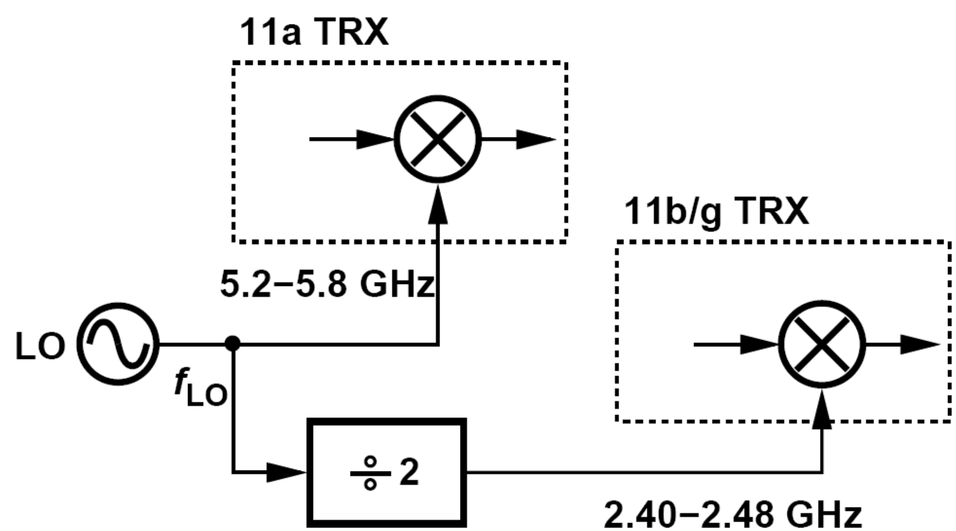
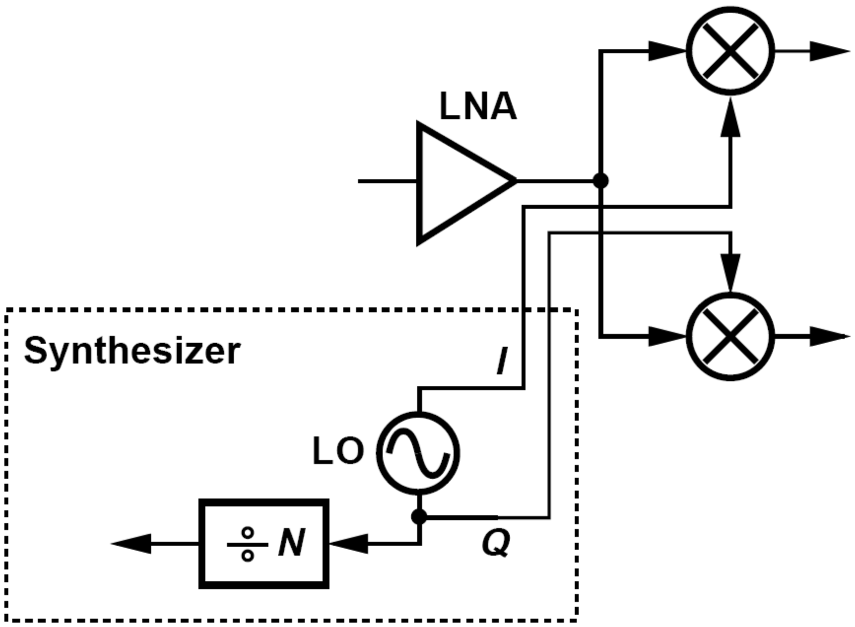
For a direct-conversion transceiver with 2.4-GHz and 5-GHz wireless bands, what is the minimum acceptable tuning range if a single LO must cover both?

For the lower band, 4.8 GHz ≤ f_{LO} ≤ 4.96 GHz.
Thus, a total tuning range of 4.8 GHz to 5.8 GHz, about 20%.
Such a wide tuning range is relatively difficult to achieve in LC oscillators.



Performance Parameters: Output Voltage Swing & Drive Capability

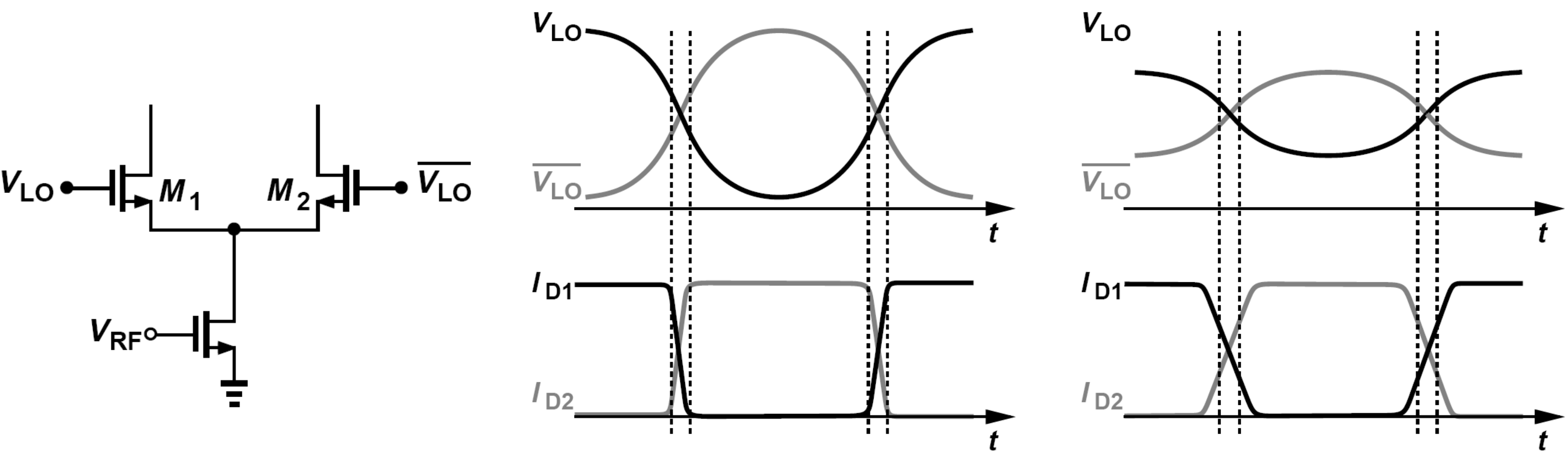
- The oscillators must produce sufficiently large output swings to ensure nearly complete switching of the transistors in the subsequent stages.



- Osciallator must drive downconversion mixers and a frequency divider, denoted by a $\div N$ block.

Performance Parameters: Drive Capability

- Typical mixers and dividers exhibit a trade-off between LO swing and the capacitance that they present at their LO port.



- Large LO swings → V_{GS1}-V_{GS2} rapidly reaches a large value, turning off one transistor.
- Smaller LO swings → steer their current with a smaller differential input.
- To alleviate the loading presented by mixers and dividers and perhaps amplify the swings, we can follow the LO with a buffer.