

Chapter 1

Oscillator

1.1 Objective

- Q1:** Design an NMOS cross-coupled LC oscillator at a frequency of 2.5 GHz
(a) Find out the power consumed by the oscillator
(b) Find out the phase noise at an offset of (i) 100 KHz and (ii) 20 MHz
- Q2:** Design a CMOS cross-coupled LC oscillator at a frequency of 2.5 GHz
(a) Find out the power consumed by the oscillator
(b) Find out the phase noise at an offset of (i) 100 KHz and (ii) 20 MHz
- Q3:** Compare CMOS and NMOS oscillators in terms of PN, voltage swing, and power dissipation.

1.2 Procedure

Step 1: Tank design - Determine the value of L and C

Choose the value of the inductor:

Larger L \rightarrow large R_p \rightarrow increase in amplitude

Larger L \rightarrow large R_p \rightarrow poor Quality factor \rightarrow poor PN

Use center-tapped inductor and give V_{DD} at the center of the inductor

Find C using

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (1.1)$$

Step 2: Estimate the R_p of the tank using *sp* analysis

Calculate R_p using the equation discussed in the tutorial and verify this by *sp* analysis (you can neglect the losses in the capacitor)

For *sp* analysis connect port to the tank and open ADE window

Analyses \rightarrow *ADE L*

From ADE window *Launch* \rightarrow *Choose*

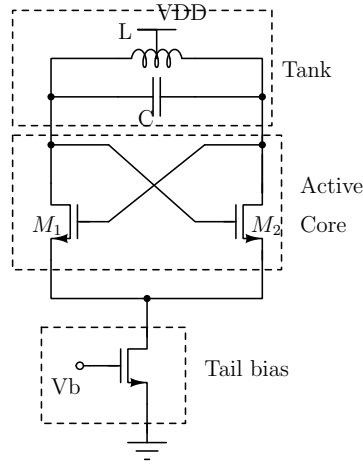


Figure 1.1: Oscillator schematic.

For running simulation

Simulation → Netlist and Run

Plot the results of sp analysis by

Results → Direct Plot → Main Form

Plot Z_{11} and measure R_P

Step 3: Design of active core

Choose both transistors with same g_m (Choose transistor with $f_T \approx 10f_0$)

For oscillator startup loop gain $> 1 \Rightarrow g_m \cdot R_P > 2$

choose $g_m \cdot R_P > 4$

Step 4: Setting transistor width for the required g_m

Run DC analysis to find the g_m of the transistor and adjust the width accordingly for the required g_m

To get the g_m *Results → Print → DC Operating Points*

click on the transistor it will print the g_m

Step 5: Tail bias

Choose the transistor width as high as possible to reduce the flicker noise upconversion from the bias transistor.

Step 6: Transient analysis

Before transient analysis give initial condition at the oscillating nodes

Simulation → Convergence Aids → Initial Condition

Also select the outputs to be plotted

Outputs → To Be Plotted → Select On Design

Now do transient analysis by choosing appropriate stop time

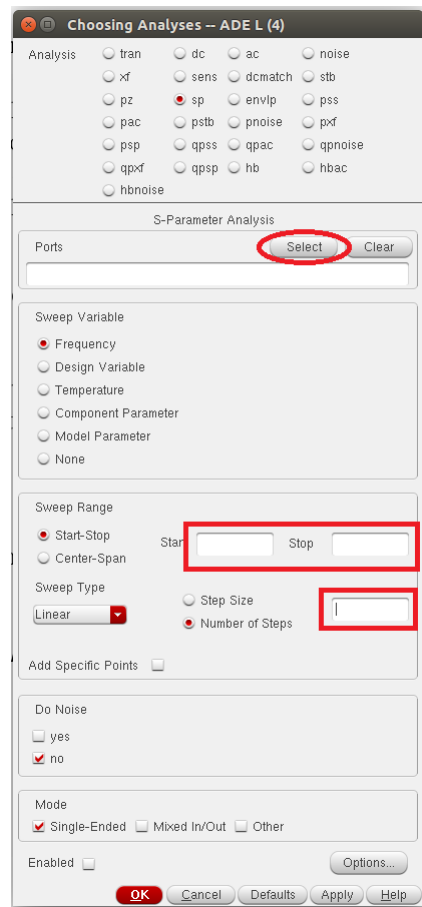


Figure 1.2: sp analysis setup.

From the Visualization and Analysis XL window calculate DFT to find the frequency of oscillations

Step 7: Plotting Phase Noise

PSS and Pnoise analysis to be done for phase noise calculation.

Periodic Steady State setup is below ??

Write the offset frequency range, where phase noise to be calculated, on the *output frequency sweep range* in the pnoise setup window

To plot phase noise

Results → *Direct Plot* → *Main Form*

Step 8: Run DC analysis and find the current drawn from the V_{DD} and find the power dissipation

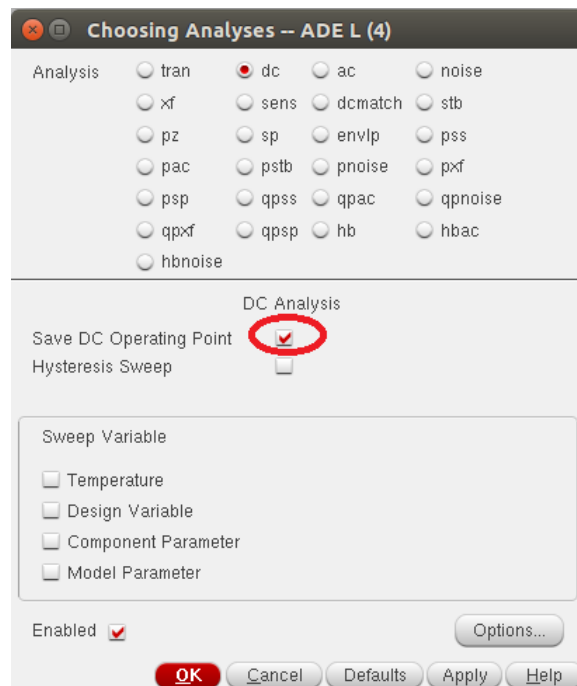


Figure 1.3: DC analysis setup.

Choosing Analyses -- ADE L (4)

Analysis: ☐ tran ☐ dc ☐ ac ☐ noise
☐ xf ☐ sens ☐ dcmatch ☐ stb
☐ pz ☐ sp ☐ envlp ☒ pss
☐ pac ☐ pstb ☐ pnoise ☐ pxf
☐ psp ☐ qpss ☐ qpac ☐ qpnoise
☐ qpxf ☐ qpdp ☐ hb ☐ hbac
☐ hbnoise

Periodic Steady State Analysis

Engine: ☐ Shooting ☒ Harmonic Balance

Tones

Name	Expr	Value	SrcId

Beat Frequency: Auto Calculate ☐

Oversample Factor:

Number of Harmonics:

Accuracy Defaults (errpreset): ☒ conservative ☐ moderate ☐ liberal

Convergence

Additional Time for Transient-Aided HB (tstab):

Save Initial Transient Results (saveinit): ☐ no ☐ yes

Harmonic Balance Homotopy Method: ▼

Oscillator ☒ Oscillator node+
Oscillator node-

☒ Calculate initial conditions (ic) automatically

☐ Use the probe-based solution method

Sweep ☐

New Initial Value For Each Point (restart): ☐ no ☐ yes

Enabled ☒

Figure 1.4: pss analysis setup.

Choosing Analyses -- ADE L (4)

Analysis: ☐ tran ☐ dc ☐ ac ☐ noise
☐ xf ☐ sens ☐ dcmatch ☐ stb
☐ pz ☐ sp ☒ pnoise ☐ pss
☐ pac ☐ pstb ☐ pxf
☐ psp ☐ qpss ☐ qpac ☐ qpnoise
☐ qpxf ☐ qpss ☐ hb ☐ hbac
☐ hbnoise

Periodic Noise Analysis

PSS Beat Frequency (Hz) 2.5G

Multiple noise ☐

Sweep type default Relative Harmonic 1

Output Frequency Sweep Range (Hz)

Start-Stop Start 10K Stop 100M

Sweep Type

Logarithmic Points Per Decade 200
☒ Number of Steps

Add Specific Points ☐

Sidebands

Maximum sideband 15

When using hb engine, default value is harms in pss.

Output

voltage Positive Output Node Select
 Negative Output Node Select

Input Source

none

Noise Type sources
 sources: single sideband (SSB) noise analysis

Noise Separation ☐ yes ☐ no
 separate noise into source and gain

Enabled ☒

Options... OK Cancel Defaults Apply Help

Figure 1.5: pnoise analysis setup.

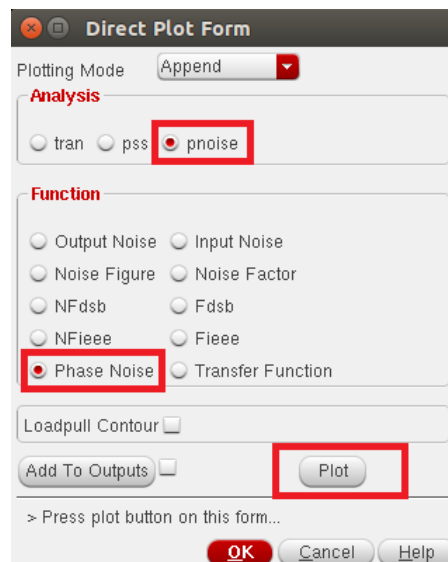


Figure 1.6: Plotting Phase Noise.

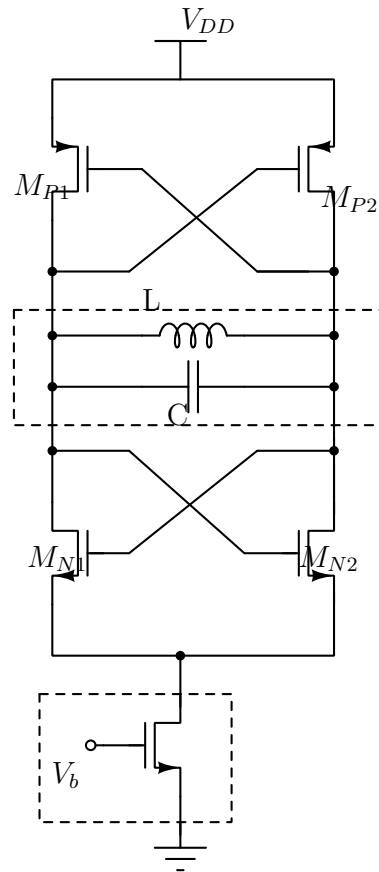
CMOS Oscillator

Figure 1.7: CMOS LC Oscillator.

Follow the same procedure, but use a normal inductor (no need center tapped inductor) as V_{DD} is given at the Source of PMOS.

Choose $W_p = 2W_n \rightarrow g_{mp} = g_{mn}$

Oscillator loop gain $> 1 \Rightarrow (g_{mp} + g_{mn}).R_P > 2 \Rightarrow g_m.R_P > 1$

For startup use 2 or 3 times higher loop gain $\Rightarrow g_m.R_P > 2$

Run pss and pnoise analysis and plot phase noise