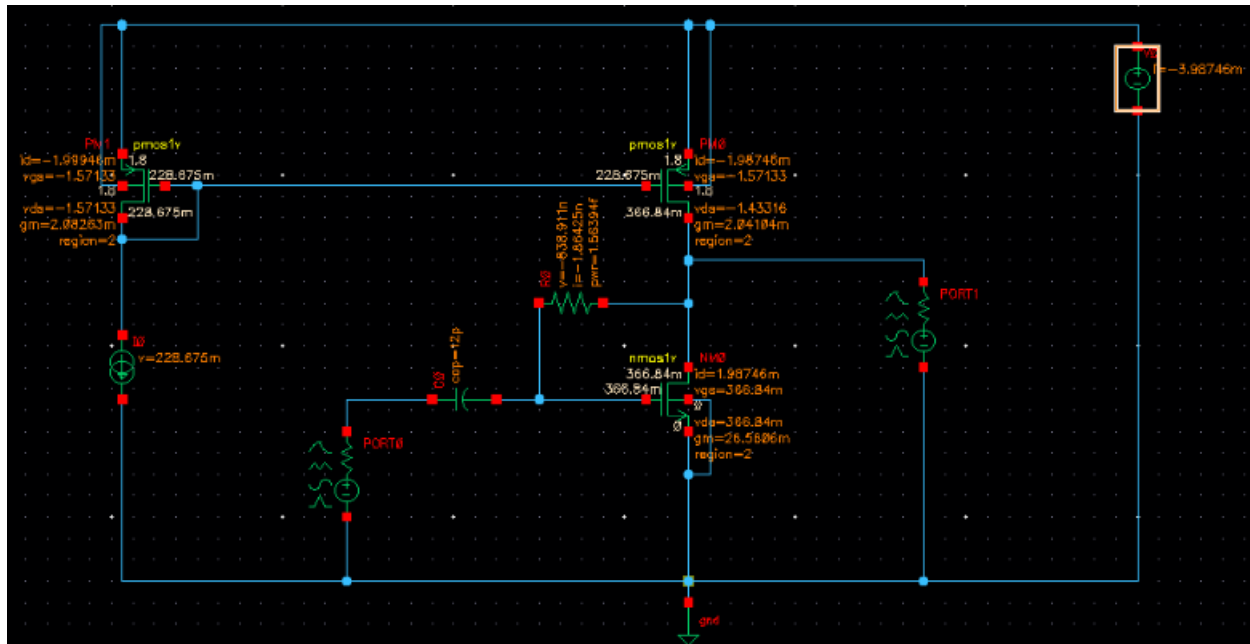


Lab #4 Low Noise Amplifier (LNA)

In this lab you will simulate a CS LNA with resistive feedback and measure its Gain, stability, NF, S11, and IP3.

Begin by drawing the circuit schematic as shown in the following figure.



- **VDD = 1.8 v.**
- **Idc = 2 mA.**
- **C1 = 12 p F.**
- **RF = 450 Ω**
- **Nmos 1v transistor has N= 3, W =30 μ m and L = 130nm.**
- **Pmos 1v transistors have W = 15 μ m and L = 600nm.**

Part (A):

For Gain, NF, S11 and Kf simulations:

- Set the properties of the **In port** as below:

The screenshot shows the 'Edit Object Properties' dialog box for an analogLib component. The 'Library Name' is 'analogLib', 'Cell Name' is 'port', 'View Name' is 'symbol', and 'Instance Name' is 'RF'. The 'User Property' section has 'IvIgnore' set to 'TRUE'. The 'CDF Parameter' section has 'Resistance' set to '50 Ohms', 'Reactance' is blank, 'Port number' is blank, 'DC voltage' is blank, and 'Source type' is 'dc'. The 'Display' column has all options set to 'off'. The 'Display small signal params' checkbox is checked. The 'Display temperature params' and 'Display noise parameters' checkboxes are unchecked. The 'OK' button is highlighted in red.

Library Name	Cell Name	View Name	Instance Name
analogLib	port	symbol	RF

User Property	Master Value	Local Value	Display
IvIgnore	TRUE		off

CDF Parameter	Value	Display
Resistance	50 Ohms	off
Reactance		off
Port number		off
DC voltage		off
Source type	dc	off
Display small signal params	<input checked="" type="checkbox"/>	off
PAC Magnitude		off
PAC Magnitude (dBm)		off
PAC phase		off
AC Magnitude	1 V	off
AC phase		off
XF Magnitude		off
Display temperature params	<input type="checkbox"/>	off
Display noise parameters	<input type="checkbox"/>	off

OK Cancel Apply Defaults Previous Next Help

- Set the type of **Load port** same as **In port** but make its resistance very large (1G ohms for example) and leave **AC magnitude** blank.
- Save your schematic.

Q1) Follow the same steps as given in the previous lab tutorials to simulate the gain, NF, S11 and Kf (stability factor) versus frequency (from 100MHz to 3GHz). Comment on the results.

Part (B):

For IP3 simulations:

- Set the properties of the **In port** as below to do the 2 tone test for checking linearity of the LNA:

The screenshot shows the 'Edit Object Properties' dialog box for an 'In port' component. The dialog is organized into a list of properties on the left and their corresponding values or controls on the right. The properties and their values are as follows:

Property	Value / Control
Resistance	50 Ohms
Reactance	off
Port number	off
DC voltage	off
Source type	sine
Frequency name 1	F1
Frequency 1	950.00M Hz
Amplitude 1 (Vpk)	off
Amplitude 1 (dBm)	PRF
Phase for Sinusoid 1	off
Sine DC level	off
Delay time	off
Display second sinusoid	<input checked="" type="checkbox"/>
Frequency name 2	F2
Frequency 2	1.05G Hz
Amplitude 2 (Vpk)	off
Amplitude 2 (dBm)	PRF
Phase for Sinusoid 2	off
Display multi sinusoid	<input type="checkbox"/>
Display modulation params	<input type="checkbox"/>
Display small signal params	<input checked="" type="checkbox"/>
PAC Magnitude	off
PAC Magnitude (dBm)	PRF
PAC phase	off

At the bottom of the dialog, there are several buttons: OK, Cancel, Apply, Defaults, Previous, Next, and Help.

- Leave the properties of **Load** port unchanged.
- Save your schematic.
- Set up the PSS analysis as shown below.

☐ xf ☐ sens ☐ dcmatch ☐ stb
☐ pz ☐ sp ☐ envlp ☒ pss
☐ pac ☐ pstb ☐ pnoise ☐ pxf
☐ psp ☐ qpss ☐ qpac ☐ qpnoise
☐ qpxf ☐ qpsp ☐ hb ☐ hbac
☐ hbnoise

Periodic Steady State Analysis

Engine ☒ Shooting ☐ Harmonic Balance

Fundamental Tones

#	Name	Expr	Value	Signal	SrcId
2	F1	950.00M	950M	Large	PORT0
1	F2	1.050	1.050	Large	PORT0

☒ Beat Frequency ☒ Auto Calculate

☐ Beat Period

Output harmonics From (Hz) Max. Order

 To (Hz)

Index	Frequency	F1	F2
15	750M	3	-2
17	850M	2	-1
19	950M	1	0
21	1.050	0	1
23	1.150	-1	2

- Run the simulation.
- Choose Results → Direct plot → PSS.
- Set up the pss simulation results setup as below.

Direct Plot Form

Plotting Mode: Append

Analysis

☐ ac ☐ sp ☒ pss

Function

☒ Voltage ☐ Current
☐ Power ☐ Voltage Gain
☐ Current Gain ☐ Power Gain
☐ Transconductance ☐ Transimpedance
☐ Compression Point ☐ IPN Curves
☐ Power Contours ☐ Reflection Contours
☐ Harmonic Frequency ☐ Power Added Eff.
☐ Power Gain Vs Pout ☐ Comp. Vs Pout
☐ Node Complex Imp. ☐ THD

Select: Port (fixed R(port))

Sweep

☐ spectrum ☒ variable

Modifier

☐ Magnitude ☒ dB20

Output Harmonic

0	0
17	850M
19	950M
21	1.050
23	1.150

Add To Outputs ☐ Replot

Then calculate IIP3 for the LNA graphically.

Appendix:

For gain simulation:

- 1) Go to the ADE and modify the ac analysis to be according to the following figure.

Choosing Analyses -- Virtuoso® Analog Design

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

AC Analysis

Sweep Variable:
☒ Frequency
☐ Design Variable
☐ Temperature
☐ Component Parameter
☐ Model Parameter

Sweep Range:
☒ Start-Stop Start: 100Hz Stop: 3G
☐ Center-Span

Sweep Type:
Linear ☐ Step Size 100
☒ Number of Steps

Add Specific Points ☐

Specialized Analyses:
None

Enabled ☒ Options...

OK Cancel Defaults Apply Help

- 2) Then run the simulation.
- 3) Go to the Main form and plot the Voltage as dB20 as shown.



The image shows a 'Direct Plot Form' dialog box with the following settings:

- Plotting Mode: Append
- Analysis: ☒ ac, ☐ sp
- Function: ☒ Voltage, ☐ Current, ☐ GD
- Select: Net
- Modifier: ☐ Magnitude, ☐ Phase, ☐ dB10, ☒ dB20
- Add To Outputs: ☐
- Replot:
- > Select Net on schematic...
- Buttons: OK, Cancel, Help

Q. Comment on your results. Comment on the results after adding a capacitor at the output equals 100fF.

For Stability simulation:

Plot “**Kf**”, you will find it in the function field as shown.

Direct Plot Form

Plotting Mode: Append

Analysis

☐ ac ☐ noise ☒ sp ☐ pss ☐ pac

Function

☐ SP ☐ ZP ☐ YP ☐ HP
☐ GD ☐ VSWR ☐ NFmin ☐ Gmin
☐ Rn ☐ m ☐ NF ☒ Kf
☐ B1f ☐ GT ☐ GA ☐ GP
☐ Gmax ☐ Gmsg ☐ Gumx ☐ ZM
☐ NC ☐ GAC ☐ GPC ☐ LSB
☐ SSB

Description: Stability Factor

Add To Outputs ☐ Plot

> Press plot button on this form...

OK Cancel Help

“**Kf**” represents K factor, which is very important to measure stability, Kf is a formula driven from S parameters to guarantee stability and the formula is given by:

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|}$$

Where Δ is the determinant of the S matrix

The important thing to know for stability is that:

$Kf > 1$ and $|B1f| < 1 \rightarrow$ System is **unconditionally stable**

$Kf < 1$ or $|B1f| > 1 \rightarrow$ System isn't guaranteed to be stable (it can be unstable under certain source or load conditions)

For Noise analysis:

- 4) Go to the ADE and modify the noise analysis to be according to the following figure.

Choosing Analyses -- Virtuoso® Analog Design En x

Sweep Variable

☒ Frequency
☐ Design Variable
☐ Temperature
☐ Component Parameter
☐ Model Parameter

Sweep Range

☒ Start-Stop Start Stop
☐ Center-Span

Sweep Type

▼

Add Specific Points ☐

Output Noise

▼ Positive Output Node
Negative Output Node

Input Noise

▼ Input Port Source

- 5) Then run the simulation.
- 6) Go to the Main form and plot the NF as shown.

Direct Plot Form

Plotting Mode ▼

Analysis

☒ noise

Function

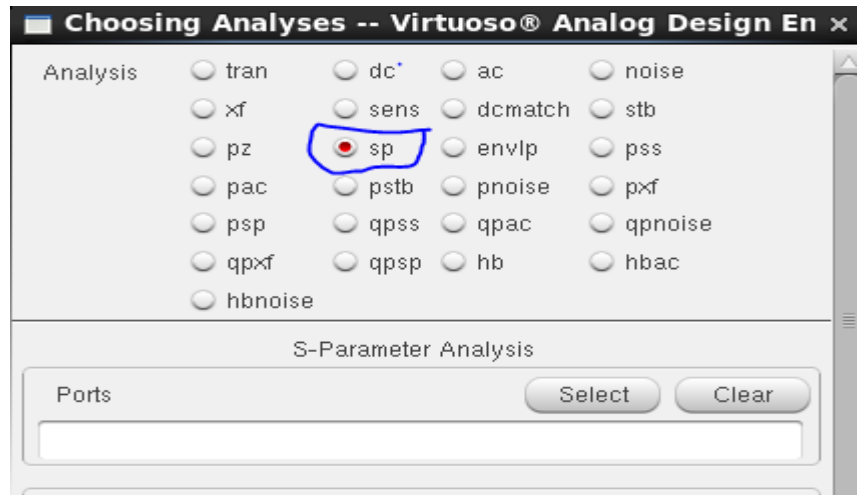
☐ Output Noise ☐ Input Noise
☒ Noise Figure ☐ Noise Factor
☐ Transfer Function

☐

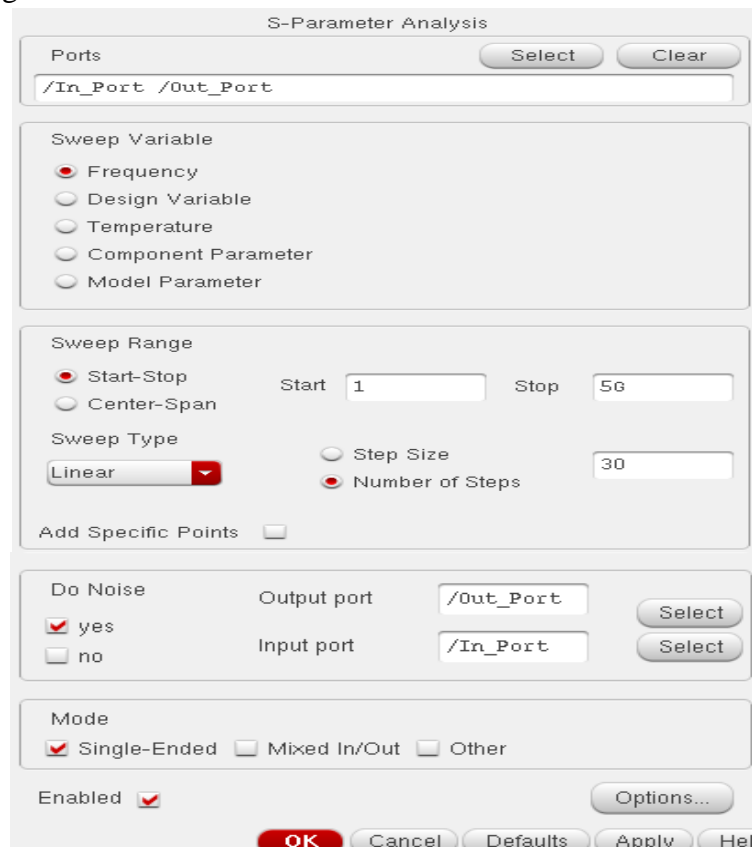
> Press plot button on this form...

For S-Parameters simulations:

- 1) Now choose “sp” analysis, which is scattering parameters as shown in the figure.



- 2) Now adjust the sp analysis as shown in the following figure.
 - First: In “**Ports**”: select In_Port, then select Out_Port
 - Check the check box in “**Do Noise**”, then select Out_Port, then In_Port as shown in the figure.



- 3) Press ok, then run simulation.
- 4) Go to the Main Form and do as the following:

sp

Function

☒ SP ☐ ZP ☐ YP ☐ HP
☐ GD ☐ VSWR ☐ NFmin ☐ Gmin
☐ Rn ☐ rn ☐ NF ☐ Kf
☐ B1f ☐ GT ☐ GA ☐ GP
☐ Gmax ☐ Gmsg ☐ Gumx ☐ ZM
☐ NC ☐ GAC ☐ GPC ☐ LSB
☐ SSB

Description: S-Parameter

Plot Type

☒ Rectangular ☐ Z-Smith ☐ Y-Smith
☐ Polar

Modifier

☐ Magnitude ☐ Phase ☒ dB20
☐ Real ☐ Imaginary

S11 S12
S21 S22

Add To Outputs ☒

> To plot, press Sij-button on this form...

OK Cancel Help

- 5) Make sure to make **Modifier in dB20**.
- 6) Press on **S11** at the bottom.