

## Lab 01

### S Parameters and Pulse Response of a Channel

## Intended Learning Objectives

This lab is divided into two parts:

- In Part 1 you will
  - Learn different methods to do the SP analysis for a multi-port channel and then plot the S parameters
- In Part 2 you will
  - Learn to do the pulse response for a given channel and get the precursors, main cursor, port cursors

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- Before we start, download the S parameters file of the channel from this link and copy it to your machine
  - <https://drive.google.com/file/d/1xys7g92T3qbKZIKTSIC2hM-CywLeli1j/view?usp=sharing>
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## PART 1: Simulating S-parameters for Channel

In this part, we will have the S-parameters file (channel s4p) for a channel and we will use it to simulate the channel response

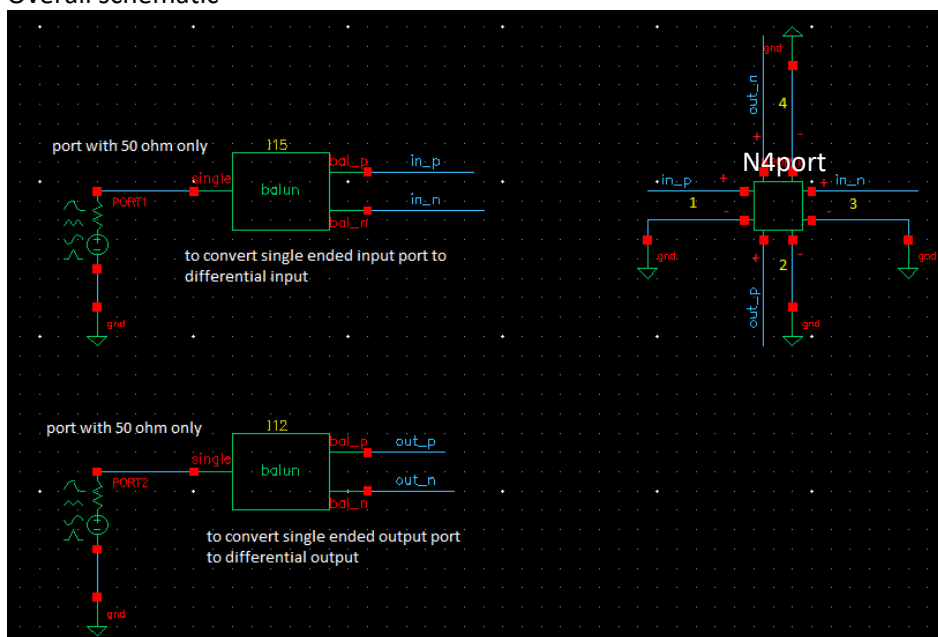
Required outputs:

- AC magnitude and phase (S21 from 0 Hz to 20 GHz)

**We will have two methods to obtain the S21 for the given channel ... Let's start**

### Method 1:

Overall schematic



### 1- Placing the n4port

- Create new schematic
- Place n4port from analogLib . This is a 4 port channel symbol. We will use it to load the channel model inside it
- Open the n4port properties and load the S parameters data file by writing the path of the s4p (eg: /home/work/desktop/channel.s4p)
- Make sure that you have 50 ohm characteristic impedance in the n4port

CDF Parameter	Value	Display
S-parameter data file	/ork/Desktop/channel.s4p	off
Advanced transient parameters	<input type="checkbox"/>	off
Noise parameters	<input type="checkbox"/>	off
Rarely used parameters	<input type="checkbox"/>	off
Model name		off
Enable mixed mode	<input type="checkbox"/>	off
The order of indices		off
Characteristic impedance	50 Ohms	off
Enable passive checker	<input type="checkbox"/>	off
Hspice Interpolation method	linear	off
Delay frequency		off
Extracts a system delay	<input checked="" type="checkbox"/>	off
Temperature difference		off
High freq extrapolate method	3	off
Linear interpolation data type	MA	off
Low freq extrapolate method	1	off
Enable noise passive checker	<input checked="" type="checkbox"/>	off
Precondition factor keyword	0.75	off
Enable rational function	<input type="checkbox"/>	off
Reuse rational function data	2	off
Method of smooth	0	off
Width of the smoothing window		off
Stamping method		off

OK Cancel Apply Defaults Previous Next Help

## 2- Placing the ports

- Place two PORTS from analoglib , each one has 50 ohm (properties of the port are in the picture)
- These two PORTS will represent the input and the output of the channel

The screenshot shows the 'Edit Object Properties' dialog box for a port component. The dialog is organized into several sections:

- Apply To:** 'only current' and 'instance' are selected.
- Show:** 'system' is unchecked, while 'user' and 'CDF' are checked.
- Buttons:** 'Browse' and 'Reset Instance Labels Display' are available.
- Property Table:**

Property	Value	Display
Library Name	analogLib	off
Cell Name	port	off
View Name	symbol	off
Instance Name	PORT1	off
- User Property Table:**

User Property	Master Value	Local Value	Display
Ivsignore	TRUE		off
- CDF Parameter Table:**

CDF Parameter	Value	Display
Resistance	50 Ohms	off
Port number		off
DC voltage		off
Source type	sine	off
Frequency 1		off
Amplitude 1 (Vpk)		off
Phase for Sinusoid 1		off
Sine DC level		off
Delay time		off
Display modulation params	<input type="checkbox"/>	off
- Buttons:** 'Add', 'Delete', and 'Modify' are available for user properties. At the bottom, there are 'OK', 'Cancel', 'Apply', 'Defaults', 'Previous', 'Next', and 'Help' buttons.

### 3-Placing the baluns

- We need baluns because we have four ports for the n4port channel
  - The port 1 and 3 in the n4port are the input ports (differential + and -) , and the ports (2, 4) are the output ports (differential + and -)
  - While at the same time, we need to have one input for the channel and one output for the channel , then we can measure S21 (path from input to output)
  - The Balun generally converts the single ended to differential
- 
- Place two baluns from rflib
  - Open the properties of each and make sure it has input impedance = 50 ohm and output impedance = 50 ohm (properties are shown here)
  - Connect the first balun to the previously placed PORT1 and the second balun to the previously placed PORT2
  - The output of the first balun will represent the input differential to the n4port channel (so they will be connected to port1 and port 3 in the n4port symbol)
  - The output of the second balun will represent the output differential of the n4port channel (so they will be connected to port2 and port 4 in the n4port symbol)

Apply To	only current	instance
Show	<input type="checkbox"/> system	<input checked="" type="checkbox"/> user <input checked="" type="checkbox"/> CDF
<div>Browse    Reset Instance Labels Display</div>		
Property	Value	Display
Library Name	rflib	off
Cell Name	balun	off
View Name	symbol	off
Instance Name	I15	value
<div>Add    Delete    Modify</div>		
User Property	Master Value	Local Value    Display
interfaceLastCha...	20 02:30:46 1998	off
partName	balun	off
vendorName		off
CDF Parameter of view	Use Tools Filter	Display
Single input impedance	50	off
Balanced output impedance	50	off
Insertion loss (dB)	0	off
<div>OK    Cancel    Apply    Defaults    Previous    Next    Help</div>		

#### 4-Create Sp analysis

- Create ADEL for the schematic
- Create SP analysis
- In the ports, select PORT1 and PORT2 in the schematic by clicking on them
- Adjust the frequency range and the number of points per decade as shown in the picture
- Run the simulation

**Choosing Analyses -- ADE L (4)**

Analysis

<input type="radio"/> tran	<input type="radio"/> dc	<input type="radio"/> ac	<input type="radio"/> noise
<input type="radio"/> xf	<input type="radio"/> sens	<input type="radio"/> dcmatch	<input type="radio"/> acmatch
<input type="radio"/> stb	<input type="radio"/> pz	<input checked="" type="radio"/> sp	<input type="radio"/> envlp
<input type="radio"/> pss	<input type="radio"/> pac	<input type="radio"/> pstb	<input type="radio"/> pnoise
<input type="radio"/> pxf	<input type="radio"/> psp	<input type="radio"/> qpss	<input type="radio"/> qpac
<input type="radio"/> qpnoise	<input type="radio"/> qpxf	<input type="radio"/> qpsp	<input type="radio"/> hb
<input type="radio"/> hbac	<input type="radio"/> hbnoise	<input type="radio"/> hbsp	

S-Parameter Analysis

Ports

**/PORT1 /PORT2**

Sweep Variable single ended ports connected to baluns

☒ Frequency

☐ Design Variable

☐ Temperature

☐ Component Parameter

☐ Model Parameter

☐ None

Sweep Range

☒ Start-Stop Start  Stop

☐ Center-Span

Sweep Type

Logarithmic

☒ Points Per Decade

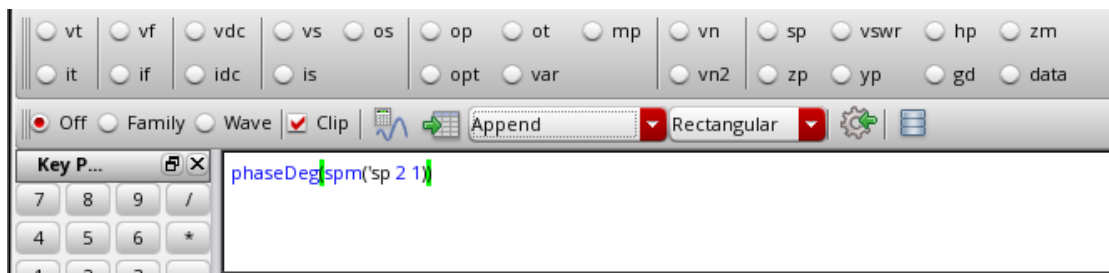
☐ Number of Steps

Add Specific Points ☐

Do Noise

### 5-plotting the outputs:

- In the ADEL, click results> Direct plot > Main form
- Select the SP
- Select plot type = rectangular
- Select S21 and plot it in dB20
- To plot the phase wrapped , write the following expression in the calculator



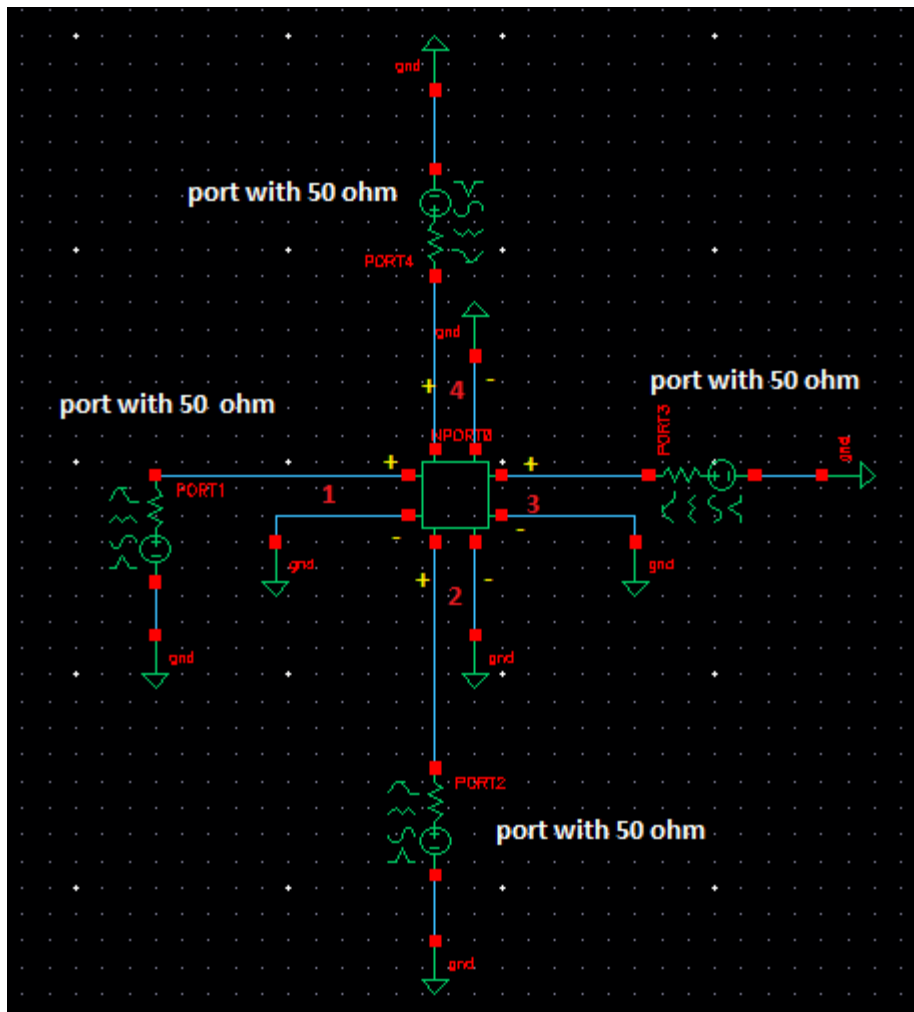
### Output plots:

#### S21 dB

#### S21 phase wrapped

## Method 2

## Overall schematic



## 1- Placing the n4port

- Same steps of placing n4port as method 1
- Make sure that you load the s4p file correctly
- Make sure about the 50 ohm characteristic impedance

## 2-Placing the ports

- Place four PORTS from analoglib , each one has 50 ohm
- Connect PORT1 to port1 +ve in n4port
- Connect PORT2 to port2 +ve in n4port
- Connect PORT3 to port3 +ve in n4port
- Connect PORT4 to port4 +ve in n4port
- (make sure about port numbers please)
- Make sure about the properties of the PORT (attached in the picture again)

The screenshot shows the 'Edit Object Properties' dialog box for a PORT component. The dialog is organized into several sections:

- Apply To:** 'only current' and 'instance' (both selected).
- Show:** 'system' (unchecked), 'user' (checked), and 'CDF' (checked).
- Buttons:** 'Browse' and 'Reset Instance Labels Display'.
- Property Table:**

Property	Value	Display
Library Name	analogLib	off
Cell Name	port	off
View Name	symbol	off
Instance Name	PORT1	off
- User Property Table:**

User Property	Master Value	Local Value	Display
Ivlsignore	TRUE		off
- CDF Parameter Table:**

CDF Parameter	Value	Display
Resistance	50 Ohms	off
Port number		off
DC voltage		off
Source type	sine	off
Frequency 1		off
Amplitude 1 (Vpk)		off
Phase for Sinusoid 1		off
Sine DC level		off
Delay time		off
Display modulation params	<input type="checkbox"/>	off
- Buttons:** 'OK' (highlighted in red), 'Cancel', 'Apply', 'Defaults', 'Previous', 'Next', and 'Help'.



### 3-Create Sp analysis

- Create ADEL for the schematic
- Create SP analysis
- In the ports, select PORT1, PORT2, PORT3, PORT4 in the schematic by clicking on them
- Adjust the frequency range and the number of points per decade as shown in the picture
- Run the simulation

**Choosing Analyses -- ADE L (8)**

Analysis

<input type="radio"/> tran	<input type="radio"/> dc	<input type="radio"/> ac	<input type="radio"/> noise
<input type="radio"/> xf	<input type="radio"/> sens	<input type="radio"/> dcmatch	<input type="radio"/> acmatch
<input type="radio"/> stb	<input type="radio"/> pz	<input checked="" type="radio"/> sp	<input type="radio"/> envlp
<input type="radio"/> pss	<input type="radio"/> pac	<input type="radio"/> pstb	<input type="radio"/> pnoise
<input type="radio"/> pxf	<input type="radio"/> psp	<input type="radio"/> qpss	<input type="radio"/> qpac
<input type="radio"/> qpnoise	<input type="radio"/> qpxf	<input type="radio"/> qpssp	<input type="radio"/> hb
<input type="radio"/> hbac	<input type="radio"/> hbnoise	<input type="radio"/> hbssp	

S-Parameter Analysis

Ports:

Sweep Variable

☒ Frequency

☐ Design Variable

☐ Temperature

☐ Component Parameter

☐ Model Parameter

☐ None

Sweep Range

☒ Start-Stop

Start:  Stop:

☐ Center-Span

Sweep Type

☒ Points Per Decade

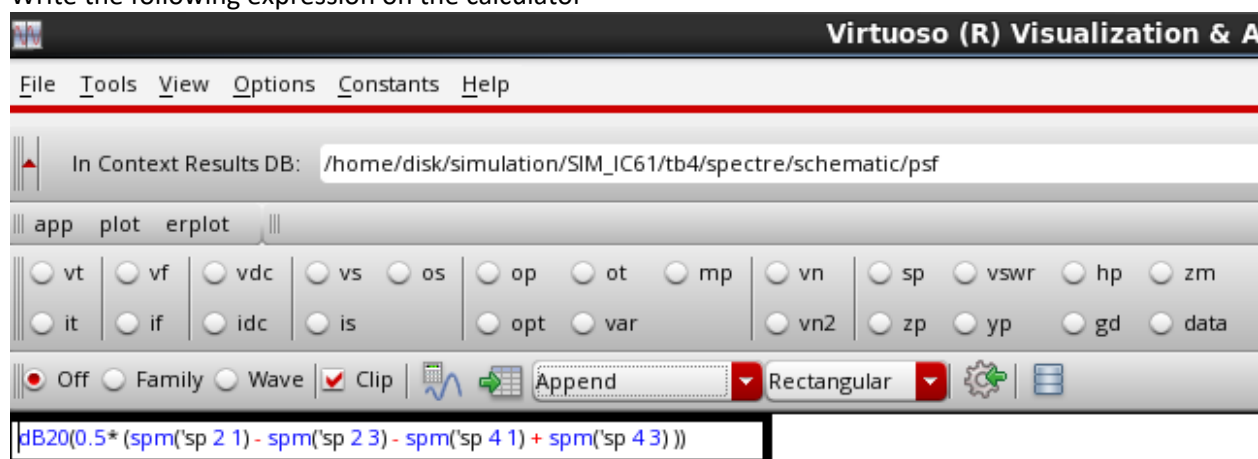
☐ Number of Steps

Add Specific Points ☐

Do Noise ☐

### 5-plotting the outputs:

Write the following expression on the calculator



The previous expression represents the S21

### Output plots: S21 dB

Appendix: Theory of conversion from single ended to differential (FYI)

Check the link for complete analysis:

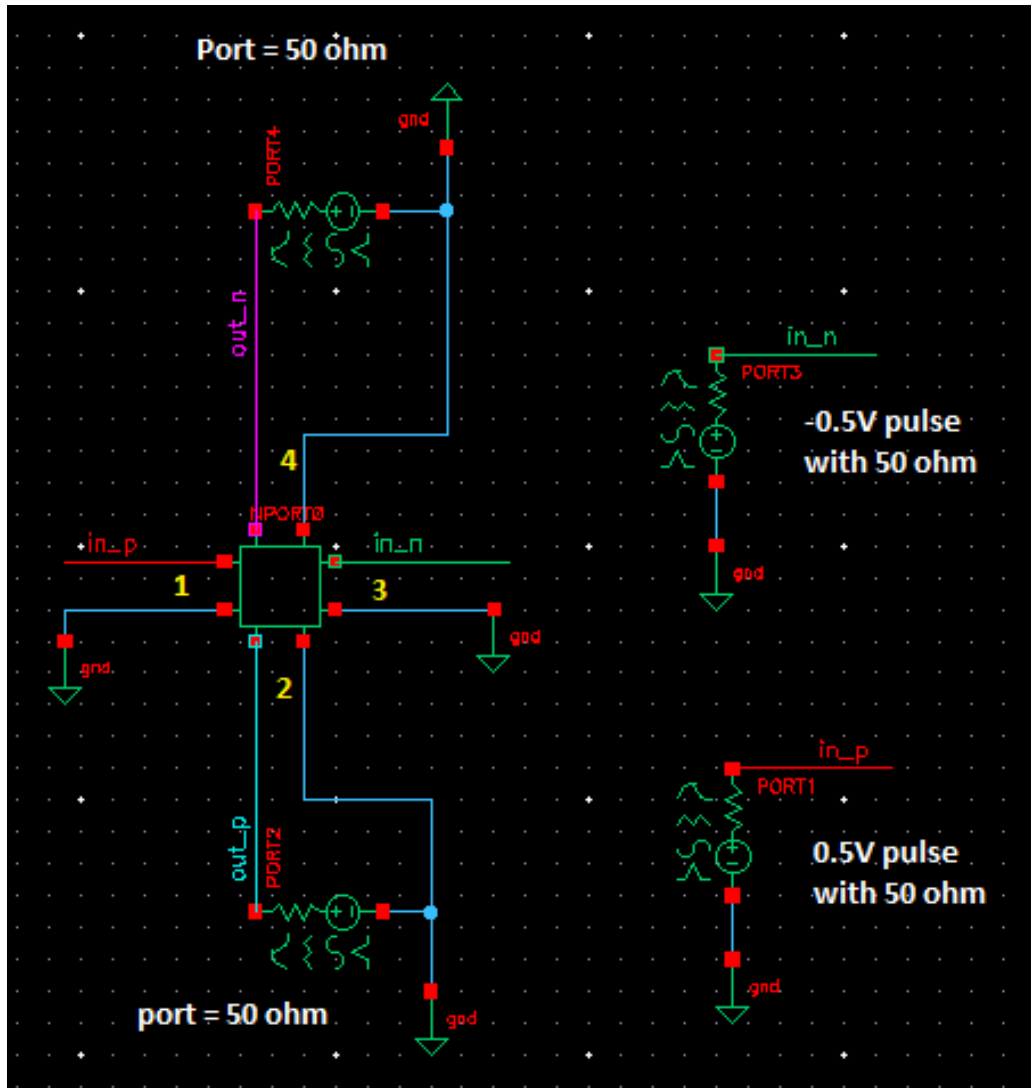
<https://www.signalintegrityjournal.com/articles/1832-a-guide-for-singleended-to-mixedmode-s-parameter-conversions>



## PART 2: Pulse Response for Channel

In this part, we will get the pulse response at 8 Gb/s

Overall schematic:



### 1- Placing the n4port

- Same steps of placing n4port as part 1
- Make sure that you load the s4p file correctly
- Make sure about the 50 ohm characteristic impedance

## 2- Placing the PORTS

- Place PORT1 connected to port1 in the n4port as shown in previous schematic
- Place PORT2 connected to port2 in the n4port as shown in previous schematic
- Place PORT3 connected to port3 in the n4port as shown in previous schematic
- Place PORT4 connected to port4 in the n4port as shown in previous schematic

### PORT1

- For PORT1, this will represent the +ve input
- Edit the properties of PORT1 to add a pulse inside it
- The pulse width is 125 ps (corresponds to 8 Gb/S)
- The fall time is 6.25ps (corresponds to 5% of the pulse width)
- The one value = 0.5V and zero value =0
- Note: the input pulse is shifted to start from 5ns

### PORT3

- For PORT3, this will represent the -ve input
- Edit the properties of PORT3 to add a pulse inside it
- The pulse width is 125 ps (corresponds to 8 Gb/S)
- The fall time is 6.25ps (corresponds to 5% of the pulse width)
- The one value = -0.5V and zero value =0
- Note: the input pulse is shifted to start from 5ns

Property	Value	Display
Library Name	analogLib	off
Cell Name	port	off
View Name	symbol	off
Instance Name	PORT1	off

Add Delete Modify

User Property	Master Value	Local Value	Display
lvignore	TRUE		off

CDF Parameter

Parameter	Value	Display
Resistance	50 Ohms	off
Port number		off
DC voltage		off
Source type	pulse	off
Delay time	5n s	off
Zero value	0 V	off
One value	500.0m V	off
Period of waveform	10u s	off
Fall time	6.25p s	off
Pulse width	125p s	off
Display small signal params	<input type="checkbox"/>	off
Multiplier		off
Open DC connection	0	off

Property	Value	Display
Library Name	analogLib	off
Cell Name	port	off
View Name	symbol	off
Instance Name	PORT3	off

Add Delete Modify

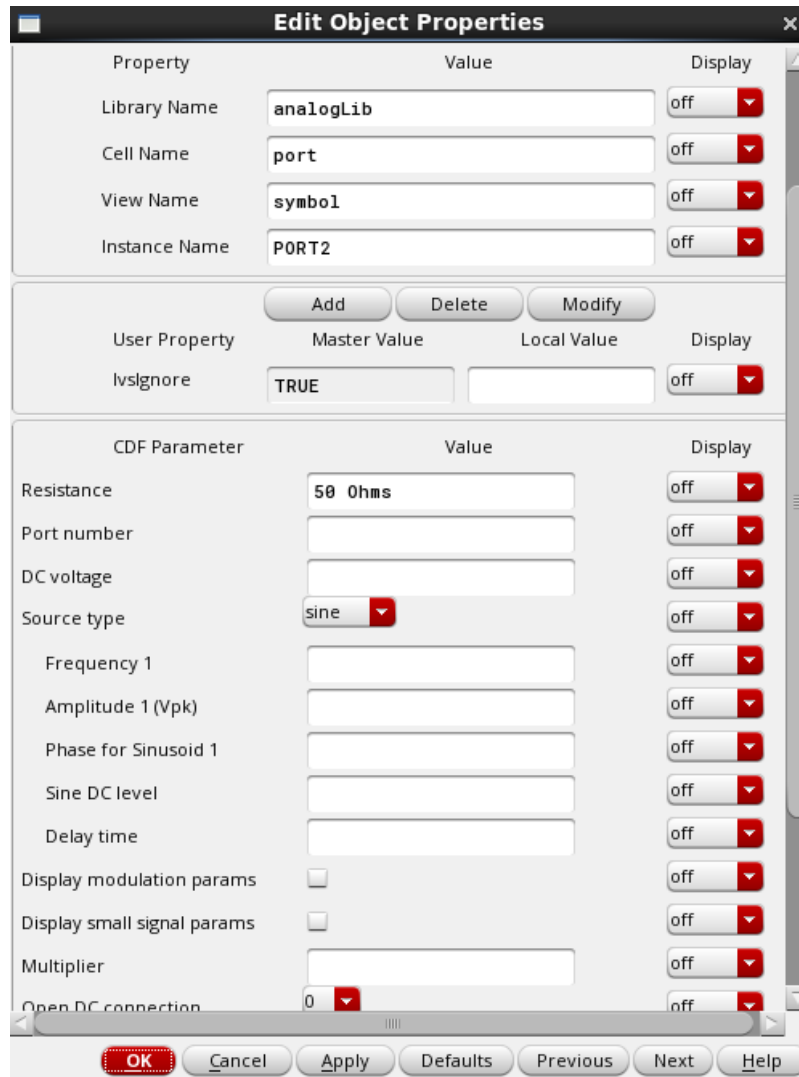
User Property	Master Value	Local Value	Display
lvignore	TRUE		off

CDF Parameter

Parameter	Value	Display
Resistance	50 Ohms	off
Port number		off
DC voltage		off
Source type	pulse	off
Delay time	5n s	off
Zero value	0 V	off
One value	-500m V	off
Period of waveform	10u s	off
Fall time	6.25p s	off
Pulse width	125p s	off
Display small signal params	<input type="checkbox"/>	off
Multiplier		off
Open DC connection	0	off

## PORT2 and PORT4

- They represent the output
- We just put 50 ohm inside PORT2 and PORT4



## 3- Create Transient analysis

- Create ADEL for the schematic
- Create transient analysis
- Let the stop time = 15ns
- Click options in the transient simulation, set the maxstep = 1ps to get high accurate
- Make sure that you select conservative
- Run the simulation

## 4- Plotting the output

- Plot the output differential of the channel (out\_p – out\_n)
- Determine the main cursor (highest point)
- Start moving by UI and record the post cursors and pre cursors
- Record your data in a table

### Required Outputs

#### Transient Output plot of the channel

#### Table including main cursor, post cursors, precursors (include at least 10 cursors)

Time	Cursor type (pre or post or main)	Value

## Appendix: Cursors example

Pulse Response	
Time (UI)	Sample (V)
-3	0.02
-2	-0.03
-1	0.03
0	0.33
1	0.25
2	0.15
3	0.06
4	0
5	-0.05
6	0.03
7	-0.02
8	0.02
9	0.01

