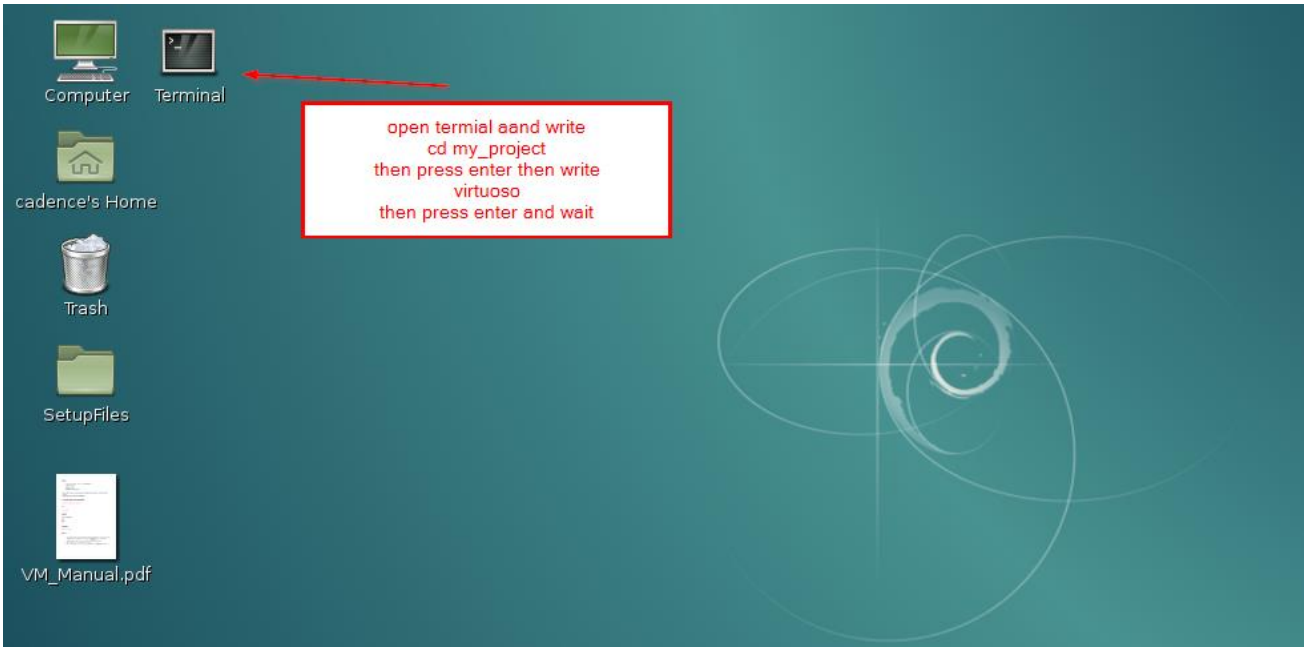
وَمَا أُوتِيتُمْ مِنَ الْعِلْمِ إِلَّا قَلِيلًا

Ain Shams University – Faculty of Engineering – ECE Dept. – Integrated Circuits Lab.
Eng. Moamen Maged and Dr. Hesham Omran

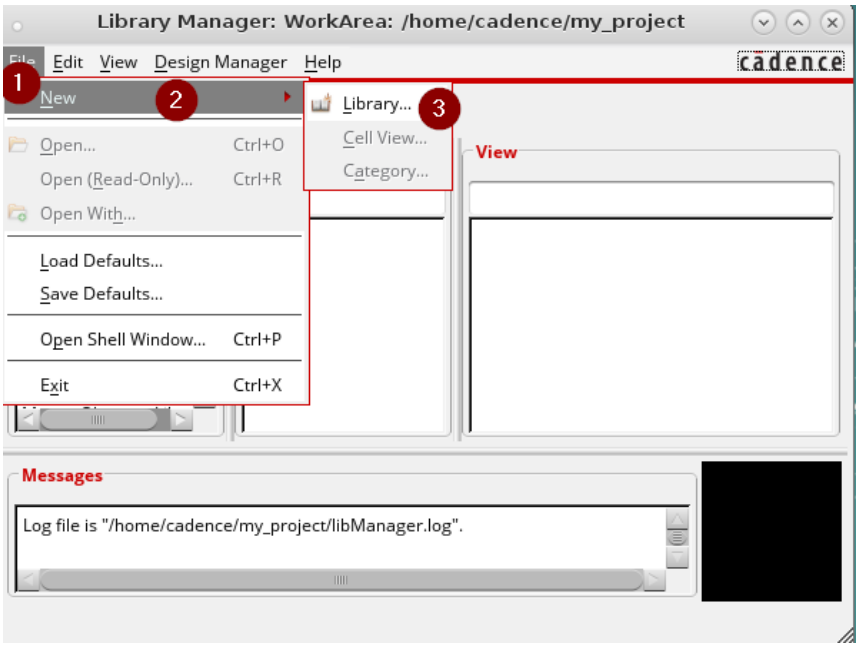
Analog IC Design
Lab 01 – Cadence Tutorial
LPF Simulation and MOSFET Characteristics

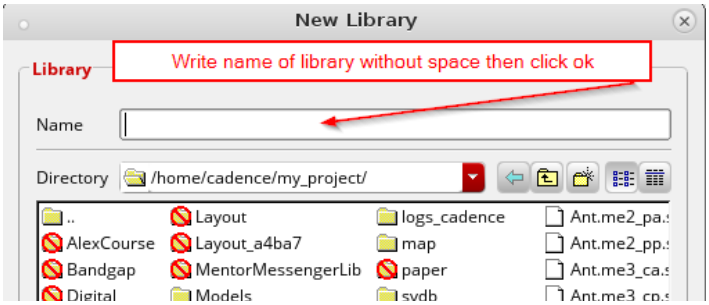
Part 1: Low Pass Filter Simulation (LPF)

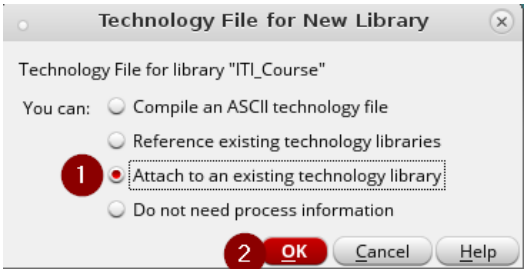
Run the tool from the terminal. Virtuoso and library manager windows will open. If you cannot see library manager window, you can open it from: Tools → Library Manger.

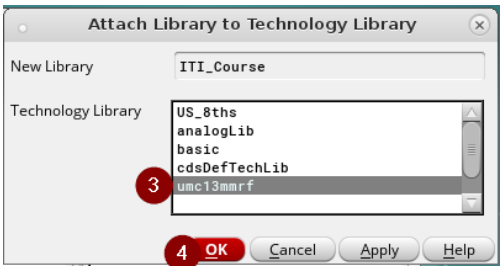


Now we will create a new library.

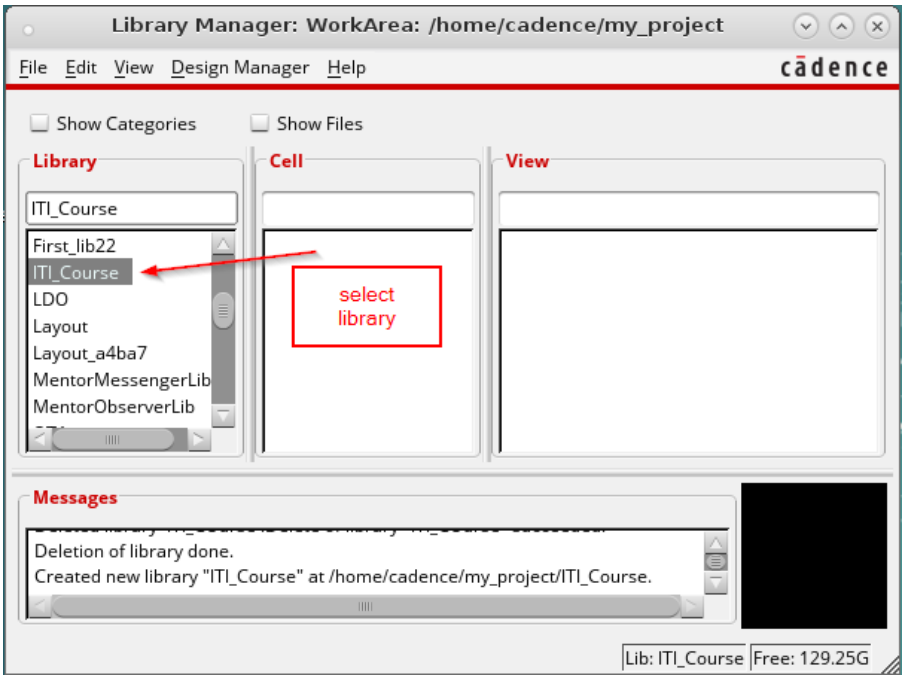


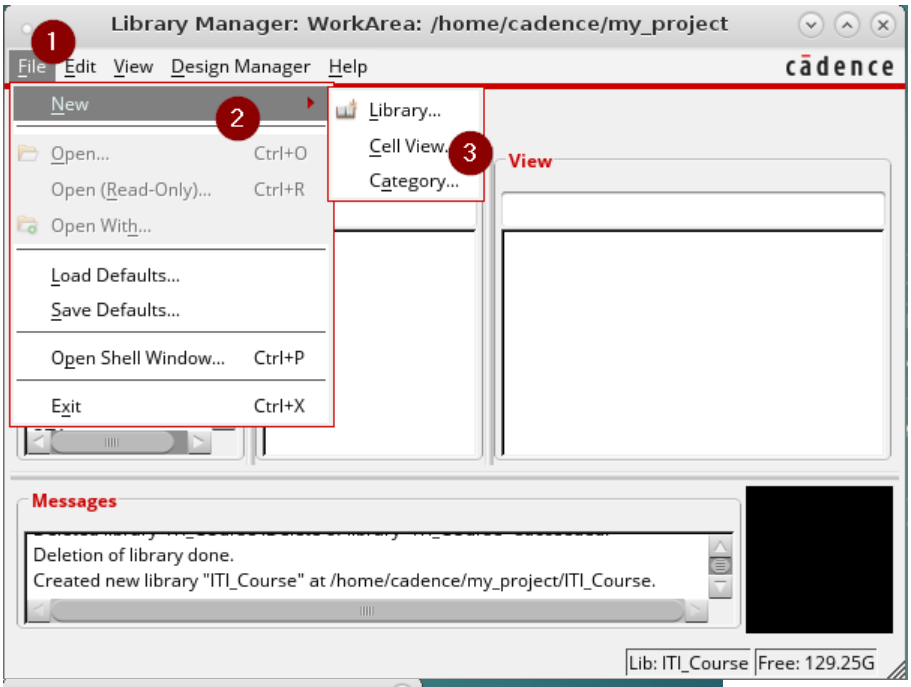


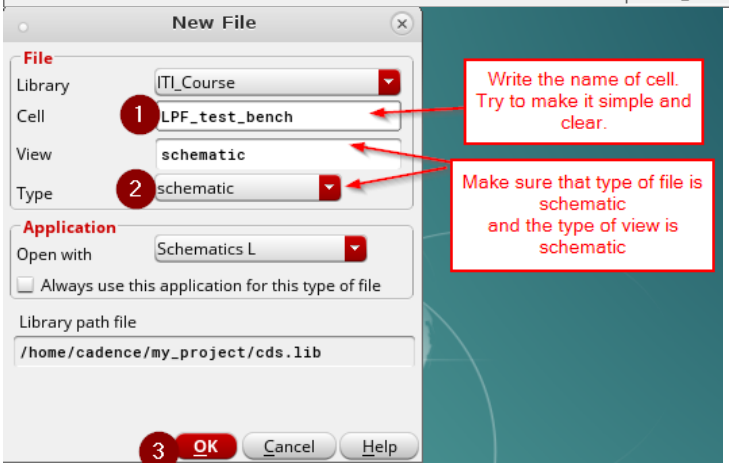




Now we want to create a new cell to draw the schematic in it.


Library Manager: WorkArea: /home/cadence/my_project
File Edit View Design Manager Help
cadence
Show Categories
Show Files
Library
Cell
View
ITI_Course
First_lib22
ITI_Course
LDO
Layout
Layout_a4ba7
MentorMessengerLib
MentorObserverLib
select library
Messages
Deletion of library done.
Created new library "ITI_Course" at /home/cadence/my_project/ITI_Course.
Lib: ITI_Course
Free: 129.25G


Library Manager: WorkArea: /home/cadence/my_project
1
File Edit View Design Manager Help
cadence
New
2
Open... Ctrl+O
Open (Read-Only)... Ctrl+R
Open With...
Load Defaults...
Save Defaults...
Open Shell Window... Ctrl+P
Exit Ctrl+X
Library...
Cell View...
Category...
3
View
Messages
Deletion of library done.
Created new library "ITI_Course" at /home/cadence/my_project/ITI_Course.
Lib: ITI_Course
Free: 129.25G


New File
File
Library
ITI_Course
Cell
1
LPF_test_bench
View
schematic
Type
2
schematic
Application
Open with
Schematics L
Always use this application for this type of file
Library path file
/home/cadence/my_project/cds.lib
3
OK
Cancel
Help
Write the name of cell.
Try to make it simple and clear.
Make sure that type of file is schematic
and the type of view is schematic

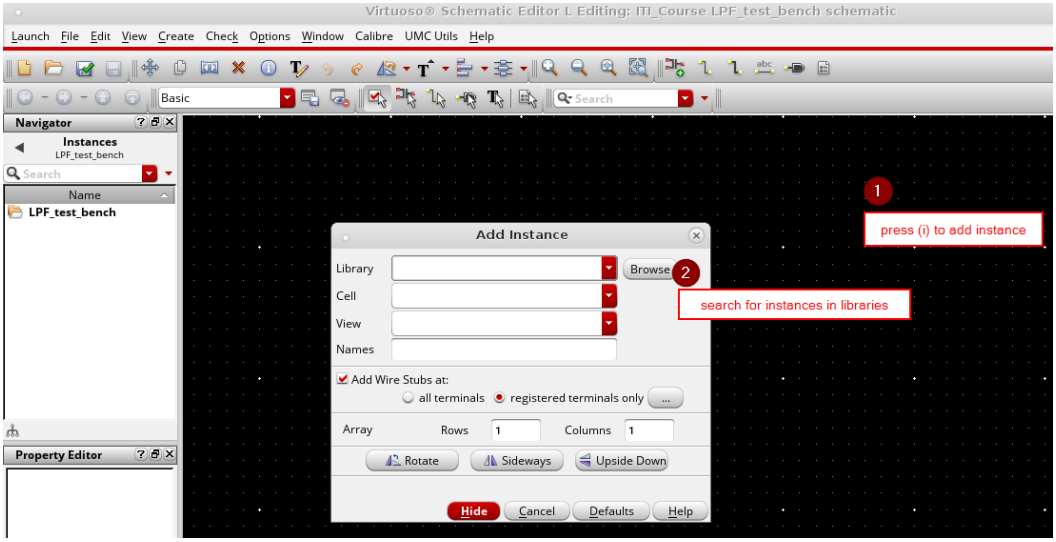
There are some useful shortcuts that will help us during schematic editing.

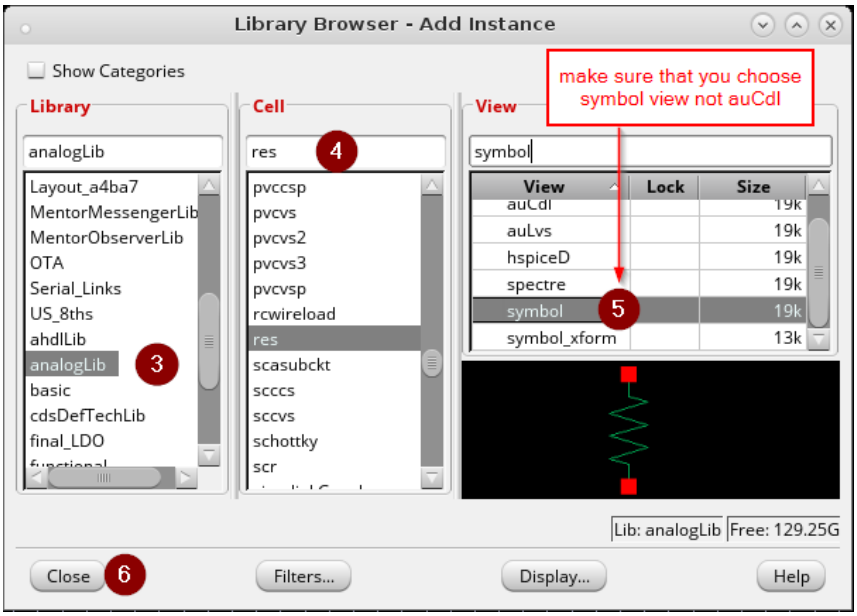
Hotkey	Function
i	Instance
q	Property
w	Wire
m	Move with connections
shift + m	Move without connections
c	Copy
r	Rotate
p	Pin
ctrl + a	Select all
d	Deselect
ctrl + d	Deselect all
u	Undo
shift +u	Redo
f	Fit
z	Zoom in
shift + z	Zoom out
shift + x	Check and Save
ctrl + e	Return (after descending into hierarchy)
l	Label

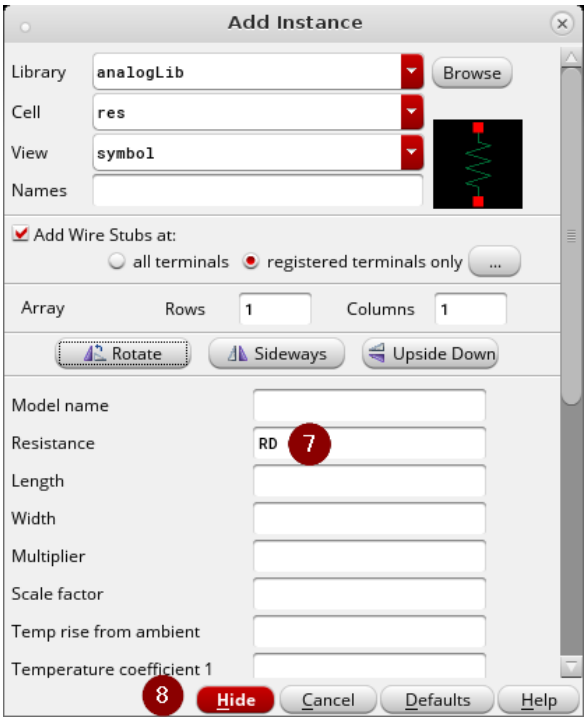
Some additional hotkeys inside the result viewer (VIVA):

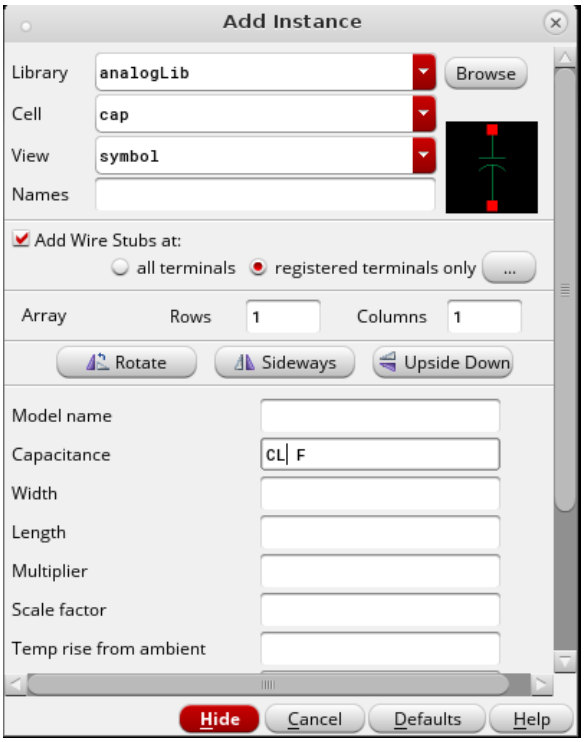
m	Add marker
a + b	Add differential marker
c	Trace
s	Add subwindow

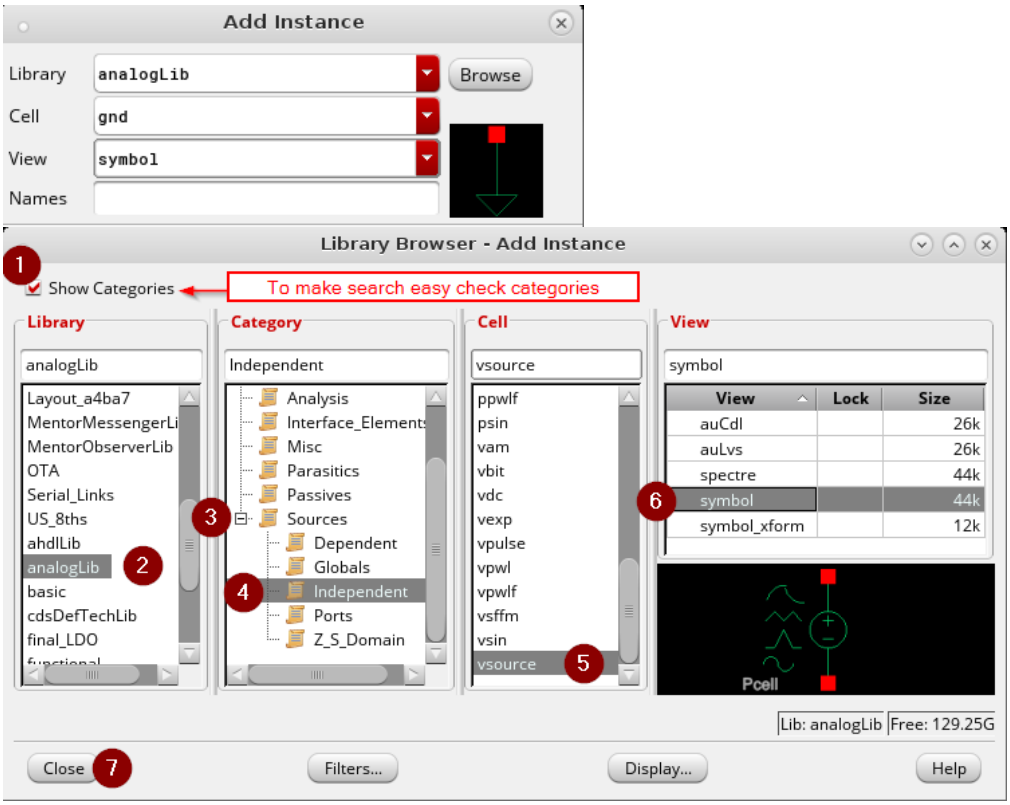
1. Transient Analysis

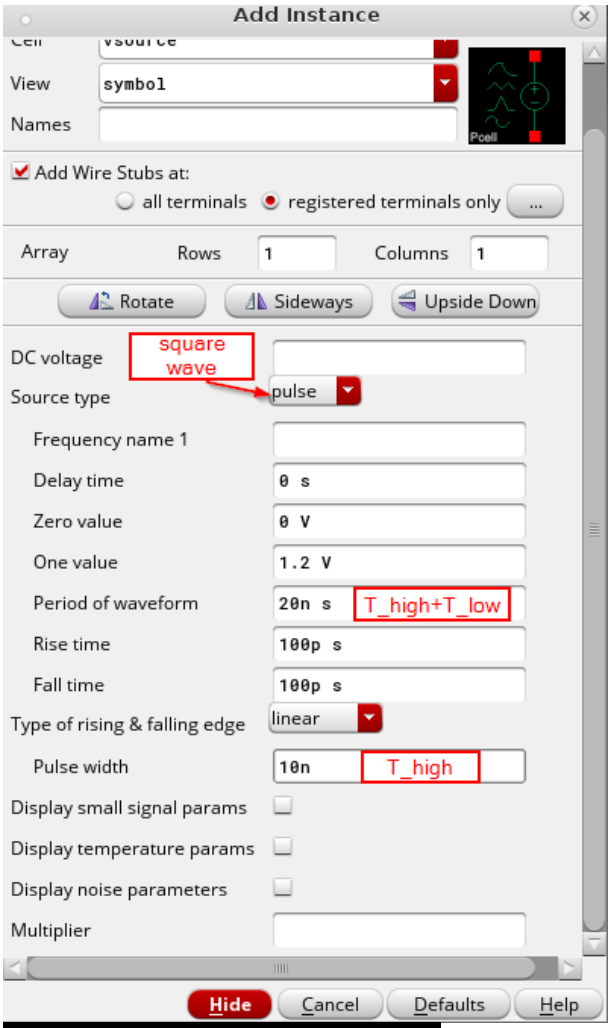



Library Browser - Add Instance
Show Categories
make sure that you choose symbol view not auCdl
Library
Cell
View
analogLib
res
symbol
Layout_a4ba7
MentorMessengerLib
MentorObserverLib
OTA
Serial_Links
US_8ths
ahdlLib
analogLib
basic
cdsDefTechLib
final_LDO
pvccsp
pvcvs
pvcvs2
pvcvs3
pvcvsp
rcwireload
res
scasubckt
scccs
sccvs
schottky
scr
View
Lock
Size
auCdl
auLvs
hspiceD
spectre
symbol
symbol_xform
19k
13k
3
4
5
Lib: analogLib
Free: 129.25G
Close
6
Filters...
Display...
Help


Add Instance
Library
analogLib
Browse
Cell
res
View
symbol
Names
Add Wire Stubs at:
all terminals
registered terminals only
...
Array
Rows
1
Columns
1
Rotate
Sideways
Upside Down
Model name
Resistance
RD
7
Length
Width
Multiplier
Scale factor
Temp rise from ambient
Temperature coefficient 1
8
Hide
Cancel
Defaults
Help

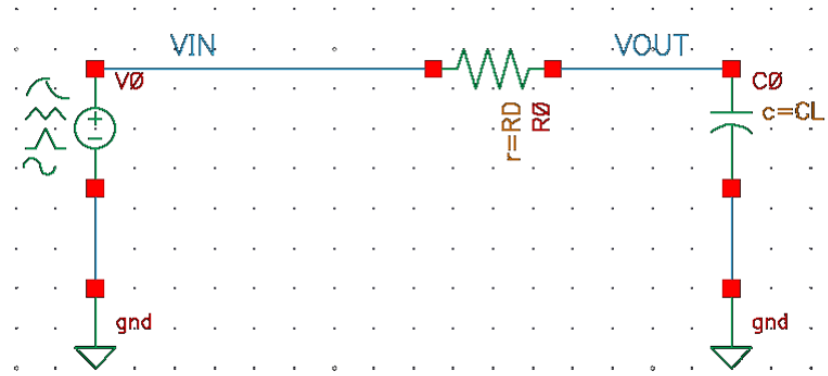

Add Instance
Library
analogLib
Browse
Cell
cap
View
symbol
Names
Add Wire Stubs at:
all terminals
registered terminals only
...
Array
Rows
1
Columns
1
Rotate
Sideways
Upside Down
Model name
Capacitance
CL F
Width
Length
Multiplier
Scale factor
Temp rise from ambient
Hide
Cancel
Defaults
Help

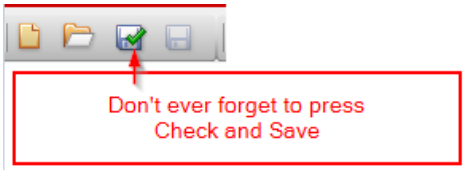

Add Instance
Library
analogLib
Browse
Cell
gnd
View
symbol
Names
Library Browser - Add Instance
1
Show Categories
To make search easy check categories
Library
Category
Cell
View
analogLib
Independent
vsource
symbol
Layout_a4ba7
MentorMessengerLi
MentorObserverLib
OTA
Serial_Links
US_8ths
ahdlLib
analogLib
basic
cdsDefTechLib
final_LDO
Analysis
Interface_Elements
Misc
Parasitics
Passives
Sources
Dependent
Globals
Independent
Ports
Z_S_Domain
ppwlf
psin
vam
vbit
vdc
vexp
vpulse
vpwl
vpwlf
vsffm
vsin
vsource
View
Lock
Size
auCdl
26k
auLvs
26k
spectre
44k
symbol
44k
symbol_xform
12k
Pcell
Lib: analogLib
Free: 129.25G
Close
Filters...
Display...
Help


Add Instance
View
symbol
Names
Add Wire Stubs at:
all terminals
registered terminals only
Array
Rows
1
Columns
1
Rotate
Sideways
Upside Down
DC voltage
square wave
Source type
pulse
Frequency name 1
Delay time
0 s
Zero value
0 V
One value
1.2 V
Period of waveform
20n s
T_high+T_low
Rise time
100p s
Fall time
100p s
Type of rising & falling edge
linear
Pulse width
10n
T_high
Display small signal params
Display temperature params
Display noise parameters
Multiplier
Hide
Cancel
Defaults
Help

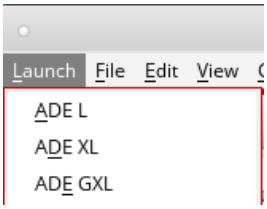

press (L)
Create Wire Name
Names
VIN VOUT
Write Labels
Expand bus names
Attach to multiple wires
Create net alias labels
Display bundles vertically
Font
Entry Style
Rotation
Hide
Cancel
Defaults
Help

Schematic of LPF

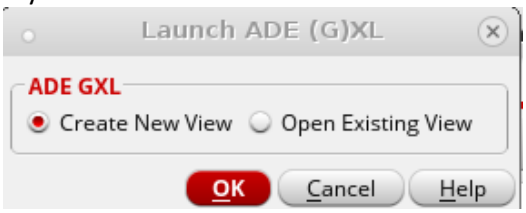


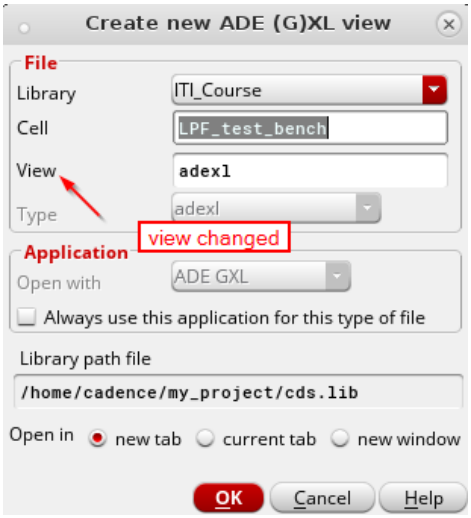


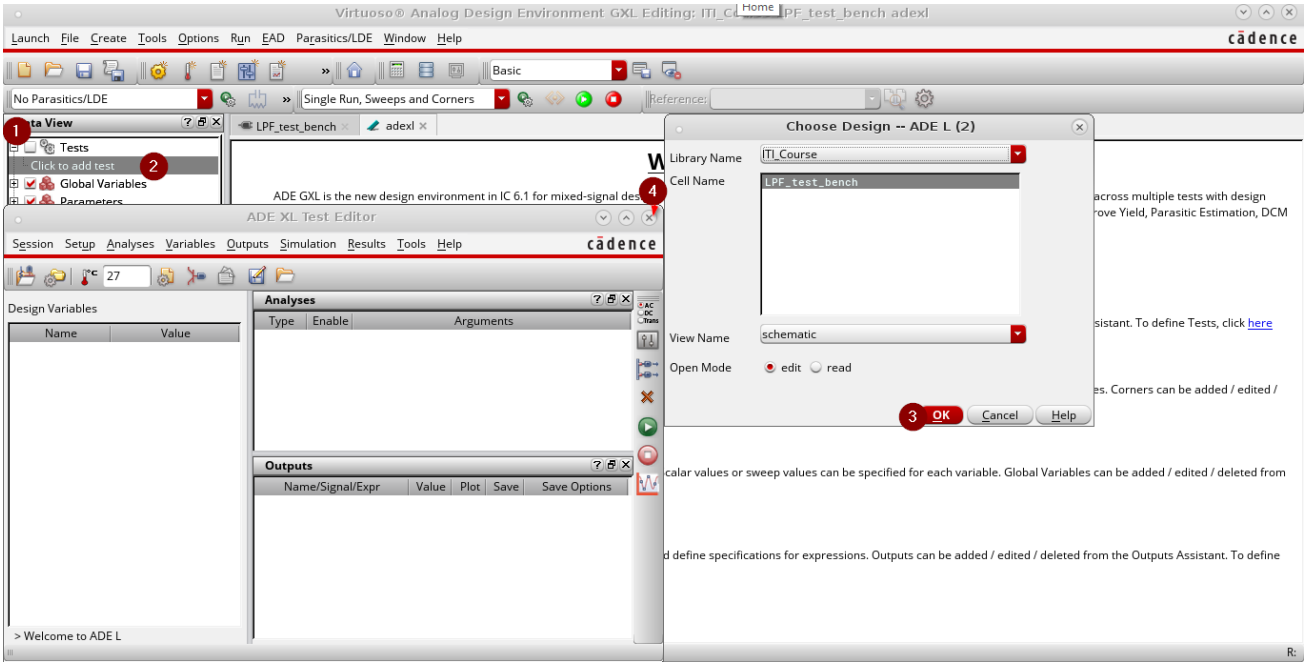
Launch ADE XL.



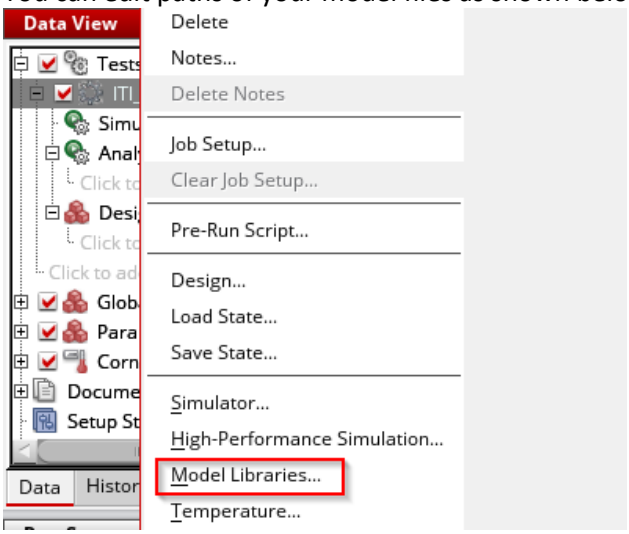
If you did not create an ADE XL view before for this schematic, select “Create New View”.

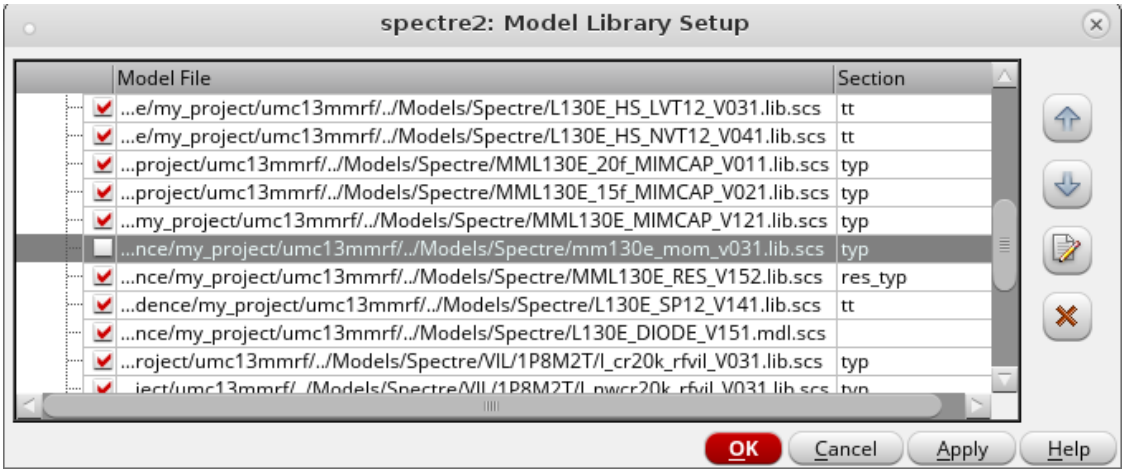


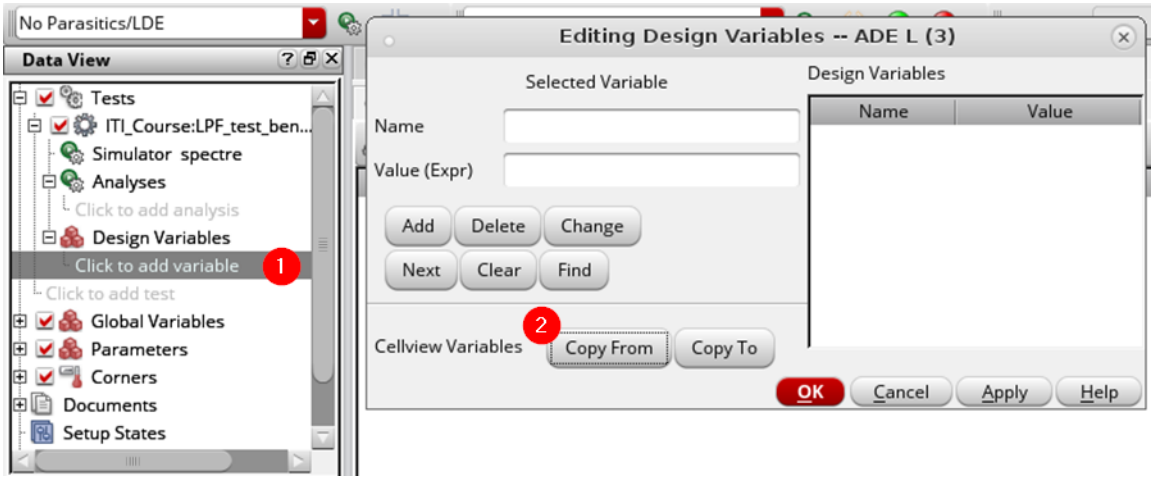


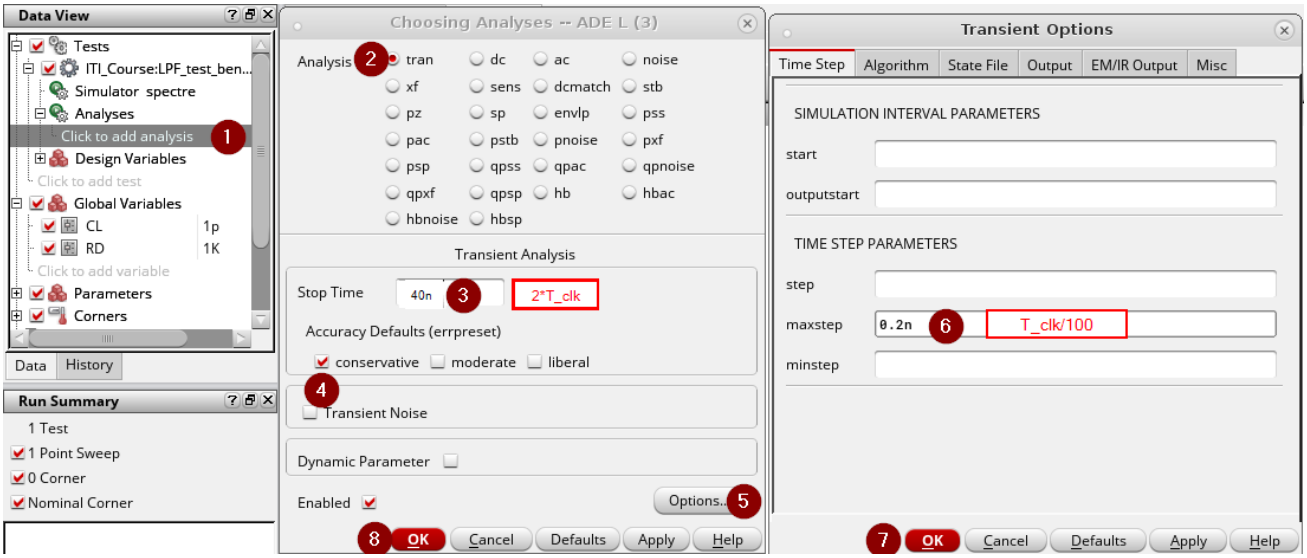


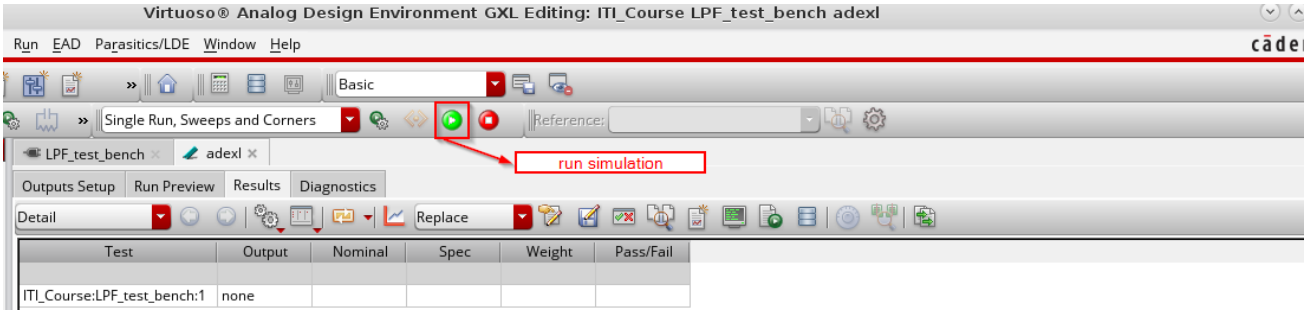
You can edit paths of your model files as shown below. If a specific file is giving you error, you can disable it.



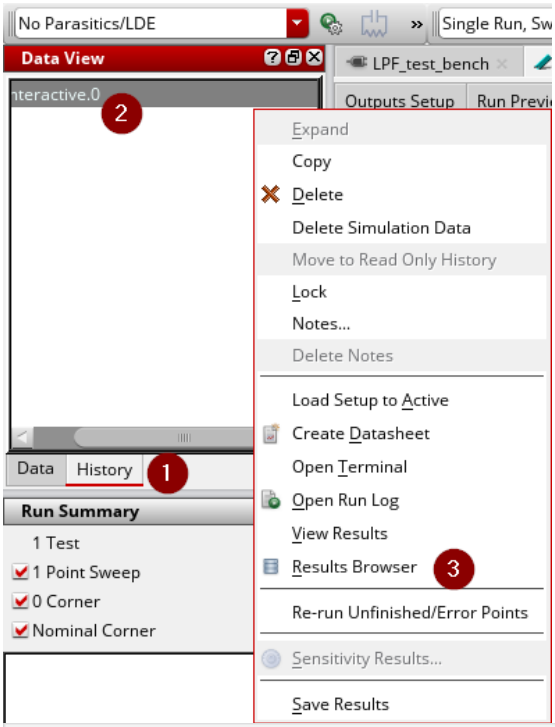


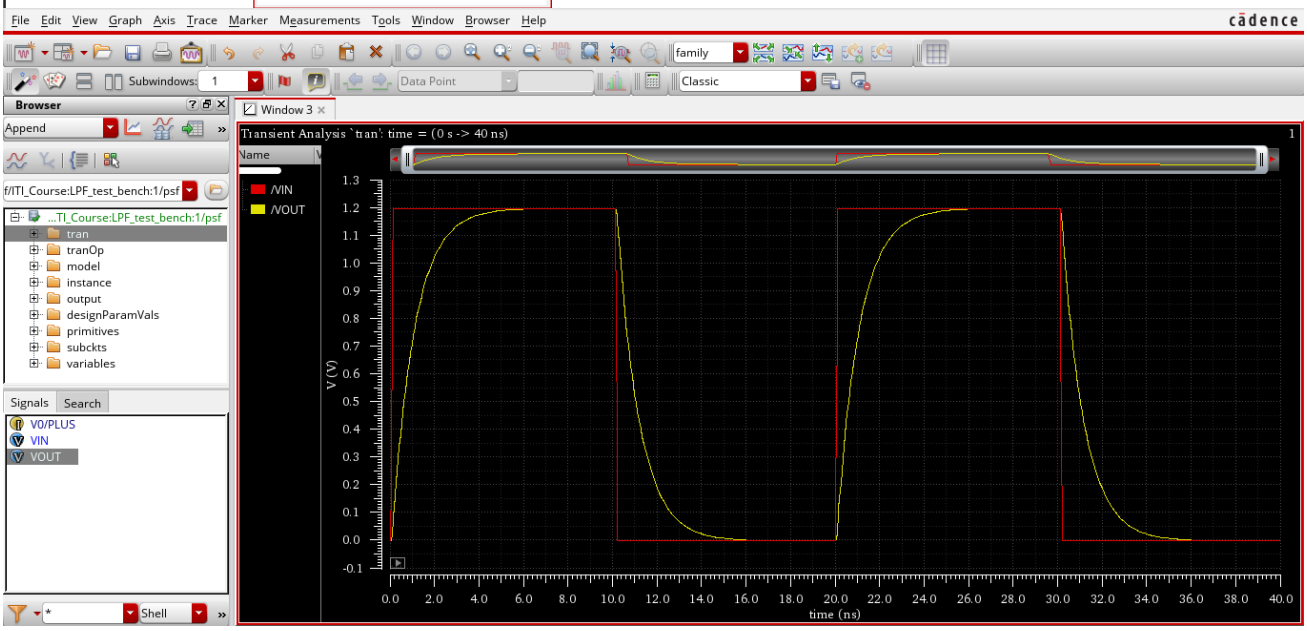


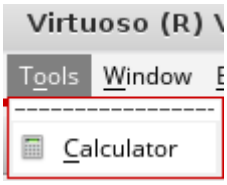


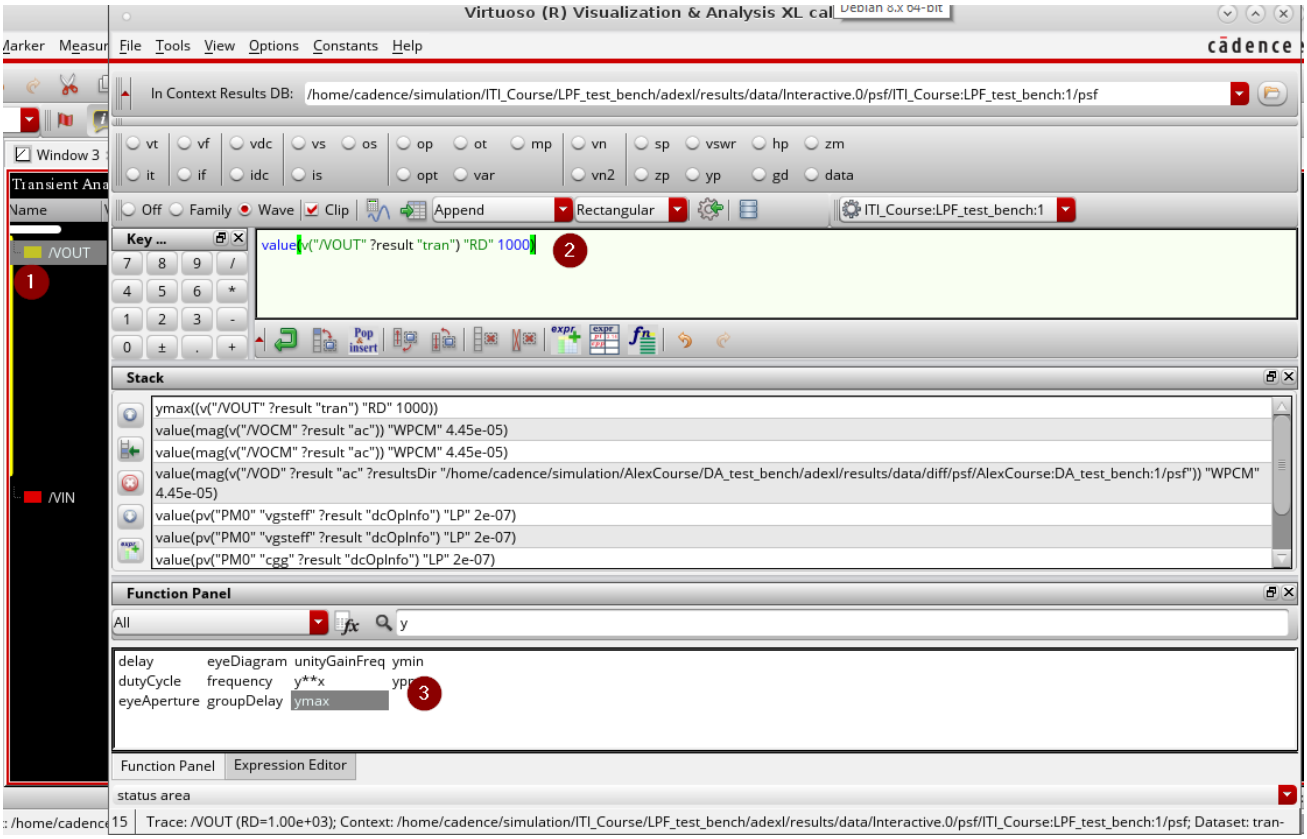


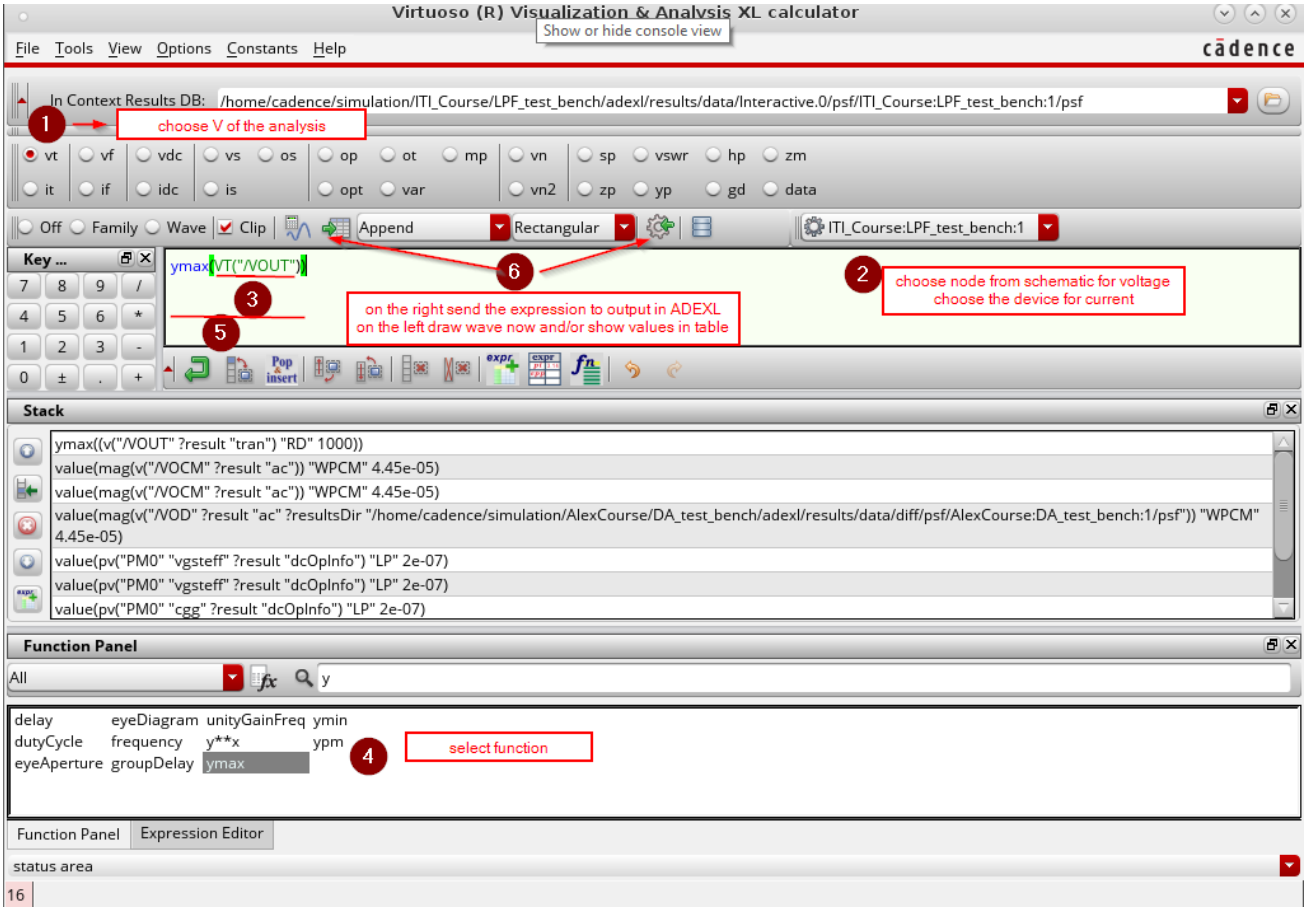
View the results from “Results Browser”. There are several other methods to view the results.

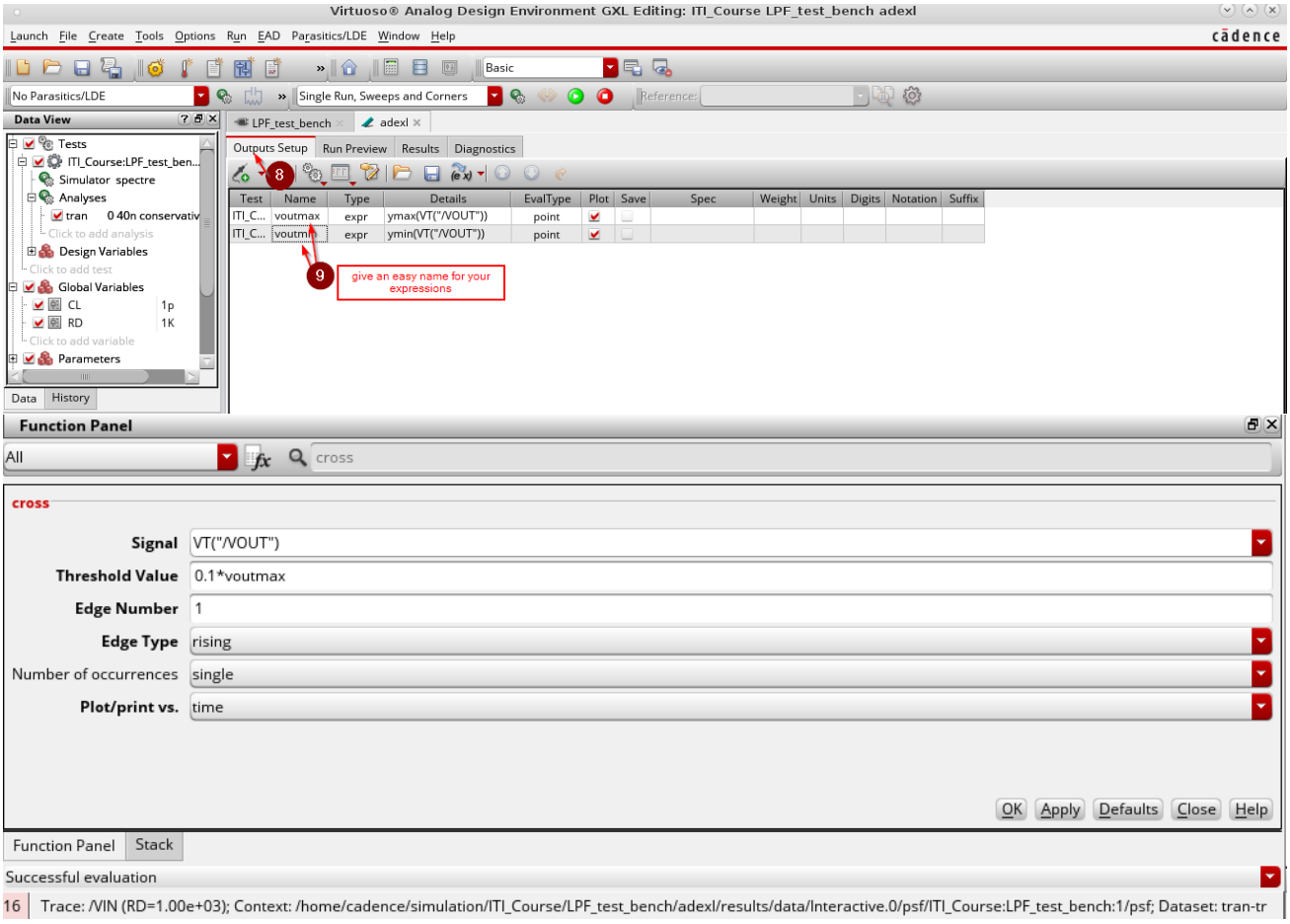

No Parasitics/LDE
Single Run, Sw
Data View
LPF_test_bench
Outputs Setup
Run Previ
nteractive.0
2
Expand
Copy
Delete
Delete Simulation Data
Move to Read Only History
Lock
Notes...
Delete Notes
Load Setup to Active
Create Datasheet
Open Terminal
Open Run Log
View Results
Results Browser
3
Re-run Unfinished/Error Points
Sensitivity Results...
Save Results
Data
History
1
Run Summary
1 Test
1 Point Sweep
0 Corner
Nominal Corner


File Edit View Graph Axis Trace Marker Measurements Tools Window Browser Help
cadence
Browser
Append
Window 3
Transient Analysis `tran': time = (0 s -> 40 ns)
/VIN
/VOUT
V (V)
time (ns)
tran
tranOp
model
instance
output
designParamVals
primitives
subckts
variables
Signals
Search
VO/PLUS
VIN
VOUT
Shell

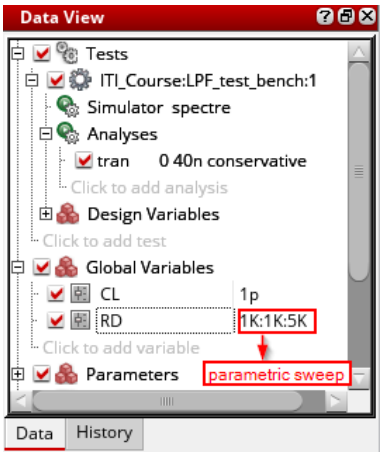

Virtuoso (R)
Tools
Window
Calculator

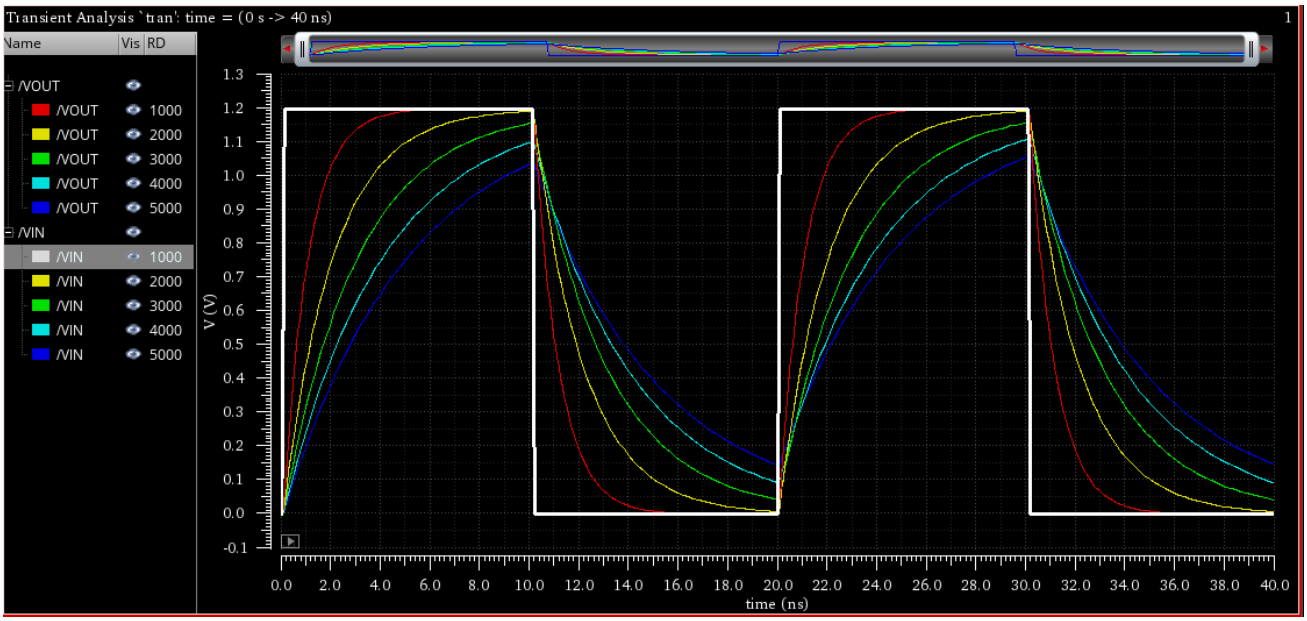

Virtuoso (R) Visualization & Analysis XL cal
File Tools View Options Constants Help
cadence
In Context Results DB: /home/cadence/simulation/ITI_Course/LPF_test_bench/adexl/results/data/Interactive.0/psf/ITI_Course:LPF_test_bench:1/psf
Append
Rectangular
ITI_Course:LPF_test_bench:1
value(v("/VOUT" ?result "tran") "RD" 1000)
Stack
ymax((v("/VOUT" ?result "tran") "RD" 1000))
value(mag(v("/VOCM" ?result "ac")) "WPCM" 4.45e-05)
value(mag(v("/VOCM" ?result "ac")) "WPCM" 4.45e-05)
value(mag(v("/VOD" ?result "ac" ?resultsDir "/home/cadence/simulation/AlexCourse/DA_test_bench/adexl/results/data/diff/psf/AlexCourse:DA_test_bench:1/psf")) "WPCM" 4.45e-05)
value(pv("PM0" "vgsteff" ?result "dcOpInfo") "LP" 2e-07)
value(pv("PM0" "vgsteff" ?result "dcOpInfo") "LP" 2e-07)
value(pv("PM0" "cgg" ?result "dcOpInfo") "LP" 2e-07)
Function Panel
delay eyeDiagram unityGainFreq ymin
dutyCycle frequency y**x ypm
eyeAperture groupDelay ymax
Function Panel
Expression Editor
status area
Trace: /VOUT (RD=1.00e+03); Context: /home/cadence/simulation/ITI_Course/LPF_test_bench/adexl/results/data/Interactive.0/psf/ITI_Course:LPF_test_bench:1/psf; Dataset: tran-


Virtuoso (R) Visualization & Analysis XL calculator
Show or hide console view
File Tools View Options Constants Help
cadence
In Context Results DB: /home/cadence/simulation/ITI_Course/LPF_test_bench/adexl/results/data/Interactive.0/psf/ITI_Course:LPF_test_bench:1/psf
choose V of the analysis
Append
Rectangular
ITI_Course:LPF_test_bench:1
ymax(VT("/VOUT"))
on the right send the expression to output in ADEXL
on the left draw wave now and/or show values in table
choose node from schematic for voltage
choose the device for current
Stack
ymax((v("/VOUT" ?result "tran") "RD" 1000))
value(mag(v("/VOCM" ?result "ac")) "WPCM" 4.45e-05)
value(mag(v("/VOCM" ?result "ac")) "WPCM" 4.45e-05)
value(mag(v("/VOD" ?result "ac" ?resultsDir "/home/cadence/simulation/AlexCourse/DA_test_bench/adexl/results/data/diff/psf/AlexCourse:DA_test_bench:1/psf")) "WPCM" 4.45e-05)
value(pv("PM0" "vgsteff" ?result "dcOpInfo") "LP" 2e-07)
value(pv("PM0" "vgsteff" ?result "dcOpInfo") "LP" 2e-07)
value(pv("PM0" "cgg" ?result "dcOpInfo") "LP" 2e-07)
Function Panel
delay eyeDiagram unityGainFreq ymin
dutyCycle frequency y**x ypm
eyeAperture groupDelay ymax
select function
Function Panel
Expression Editor
status area

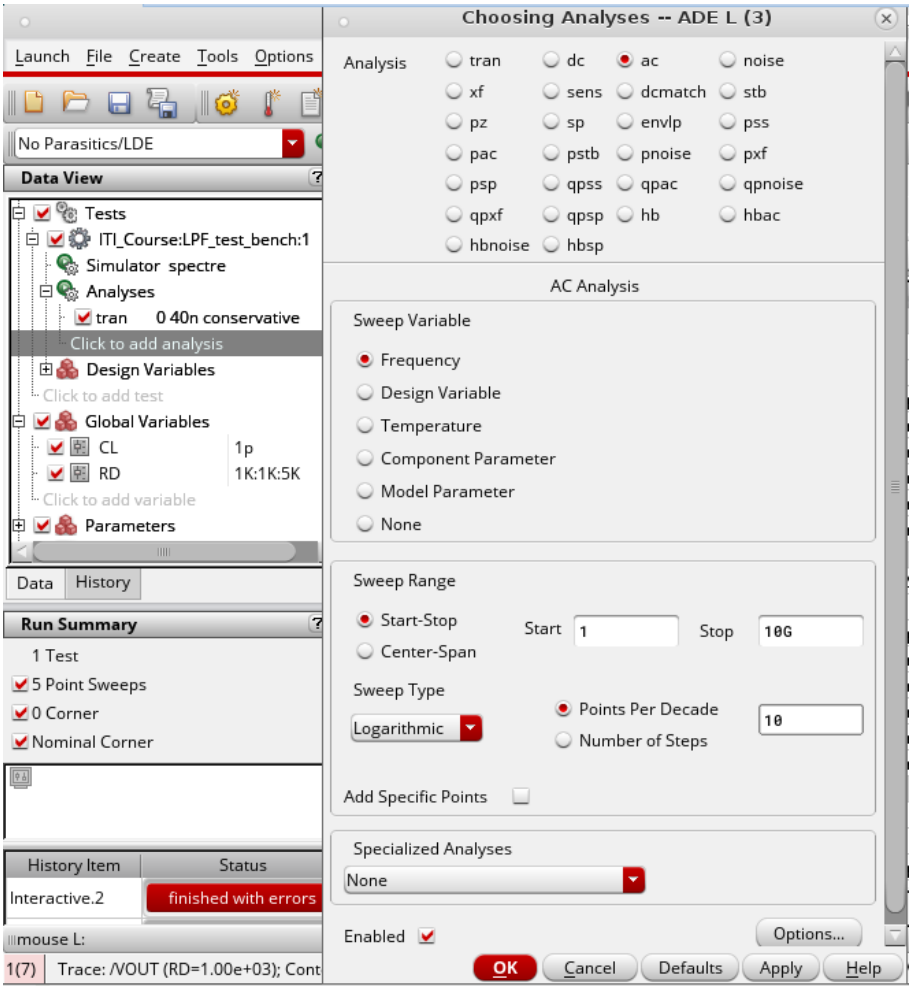


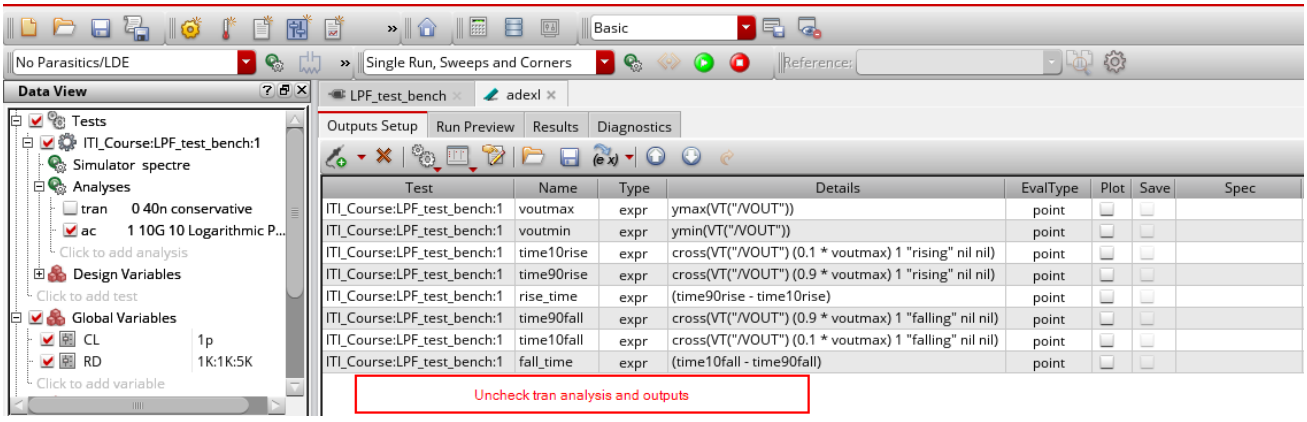
Test	Name	Type	Details	EvalType	Plot	Save	Spec	Weight	Units	Digits	Notation	Suffix
ITI_Course:LPF_test_bench:1	voutmax	expr	ymax(VT("/VOUT"))	point	☑	☐						
ITI_Course:LPF_test_bench:1	voutmin	expr	ymin(VT("/VOUT"))	point	☑	☐						
ITI_Course:LPF_test_bench:1	time10rise	expr	cross(VT("/VOUT") (0.1 * voutmax) 1 "rising" nil nil)	point	☑	☐						
ITI_Course:LPF_test_bench:1	time90rise	expr	cross(VT("/VOUT") (0.9 * voutmax) 1 "rising" nil nil)	point	☑	☐						
ITI_Course:LPF_test_bench:1	rise_time	expr	(time90rise - time10rise)	point	☑	☐						
ITI_Course:LPF_test_bench:1	time90fall	expr	cross(VT("/VOUT") (0.9 * voutmax) 1 "falling" nil nil)	point	☑	☐						
ITI_Course:LPF_test_bench:1	time10fall	expr	cross(VT("/VOUT") (0.1 * voutmax) 1 "falling" nil nil)	point	☑	☐						
ITI_Course:LPF_test_bench:1	fall_time	expr	(time10fall - time90fall)	point	☑	☐						



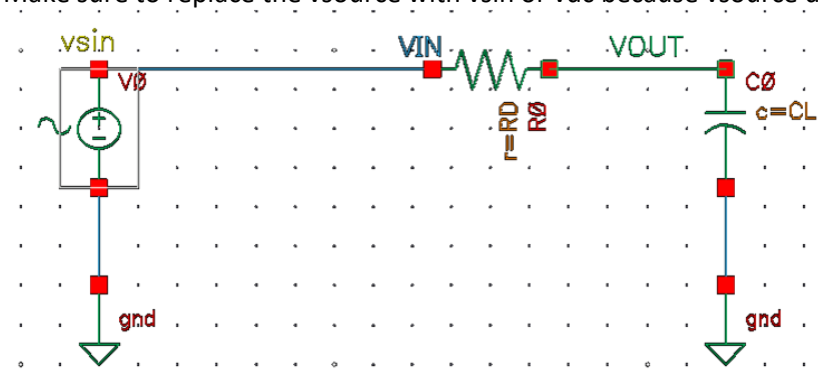


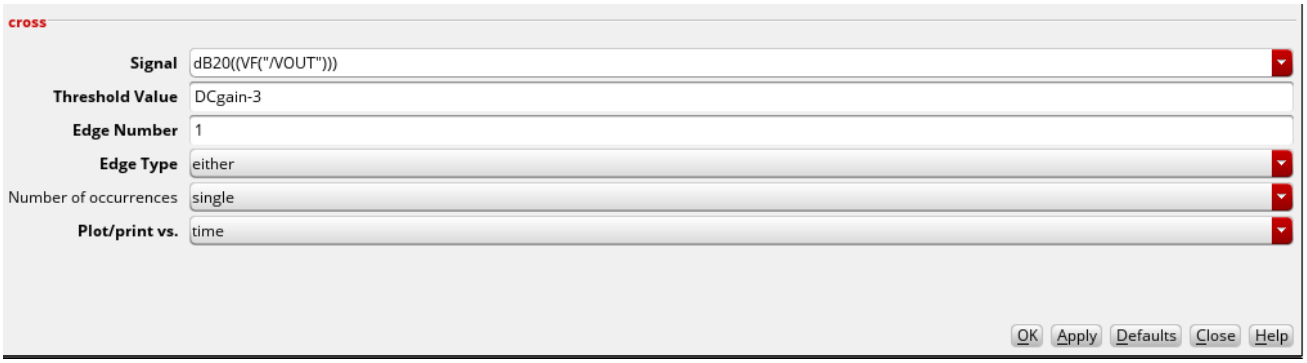
2. AC Analysis





Make sure to replace the vsource with vsin or vdc because vsource doesn't work with AC analysis

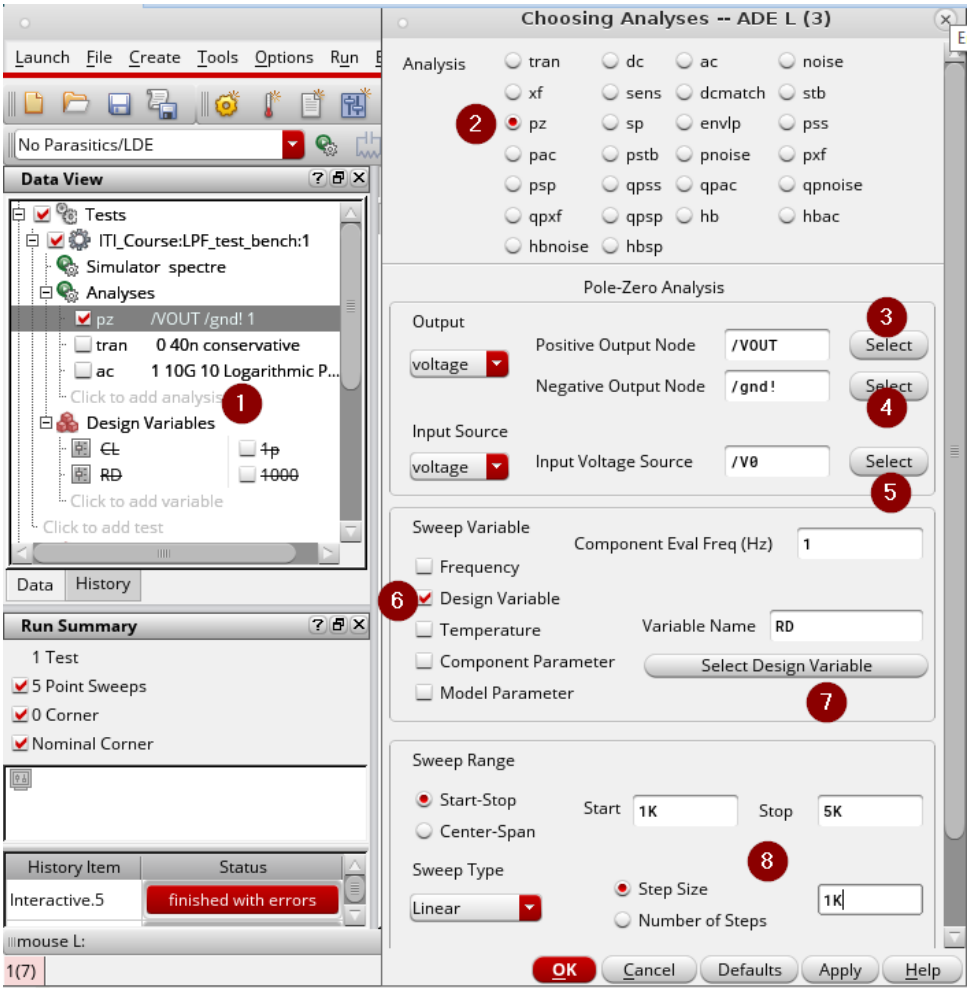


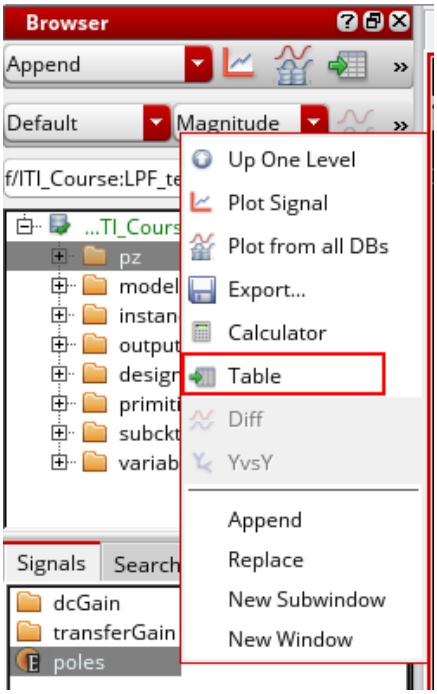


ITI_Course:LPF_test_bench:1		expr	VF("/VOUT")	point	☐	☐
ITI_Course:LPF_test_bench:1		expr	phase(VF("/VOUT"))	point	☐	☐
ITI_Course:LPF_test_bench:1	VoutdB	expr	dB20(mag(v("/VOUT" ?result "ac")))	point	☑	☐
ITI_Course:LPF_test_bench:1	DCgain	expr	ymax(VoutdB)	point	☑	☐
ITI_Course:LPF_test_bench:1	BW3dB	expr	cross(VoutdB (DCgain - 3) 1 "either" nil nil)	point	☑	☐

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI_Course:LPF_test_bench:1	VoutdB				
ITI_Course:LPF_test_bench:1	DCgain	0			
ITI_Course:LPF_test_bench:1	BW3dB	158.8M			

3. Pole Zero Analysis



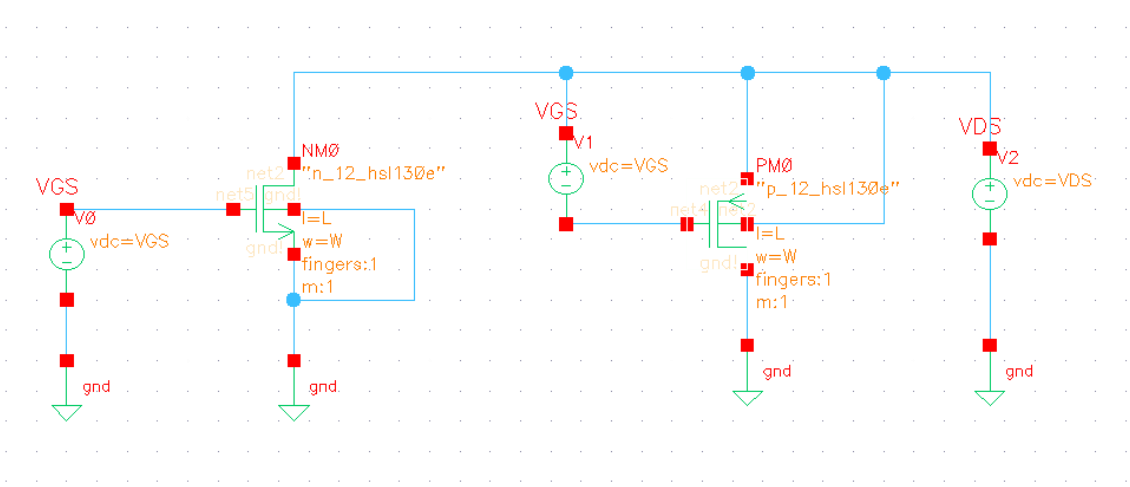


/poles

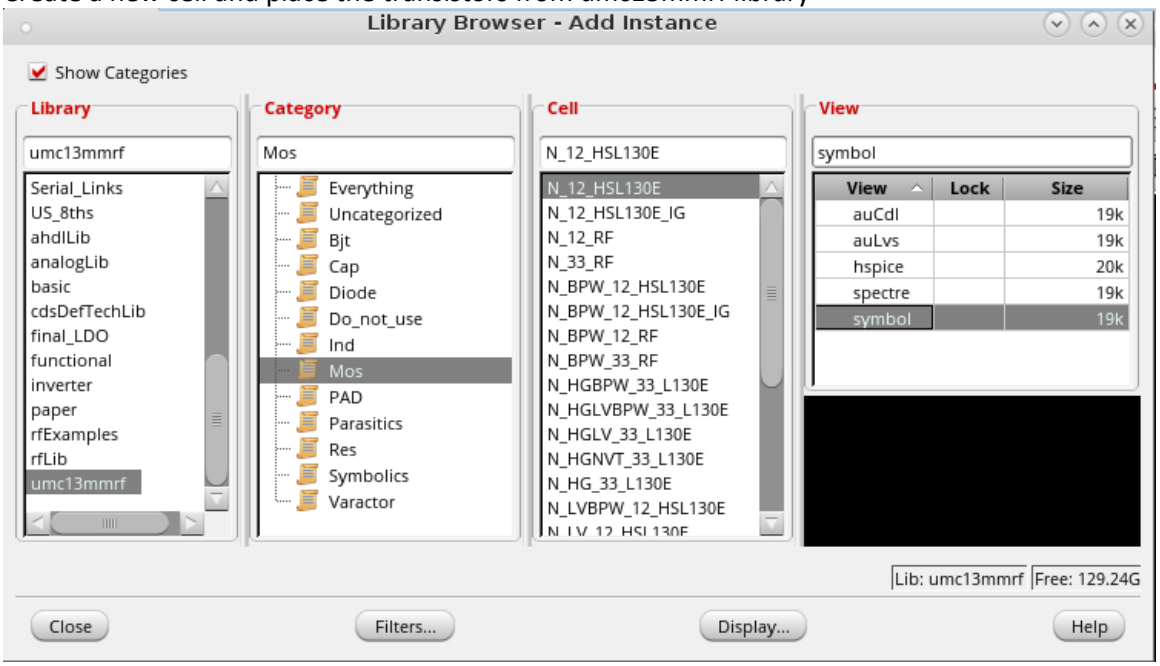
	qfactor	/poles ...0 (Hz)	/poles ...0 (Hz)	/poles ...0 (Hz)	/poles ...0 (Hz)	/poles ...0 (Hz)
1	500.0E-3	159.2E6	79.58E6	53.05E6	39.79E6	31.83E6

Part 2: MOSFET Characteristics

Create a testbench for NMOS and PMOS characterization as below.



Create a new cell and place the transistors from umc13mmrf library

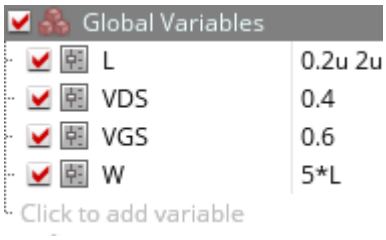


1. ID vs VGS

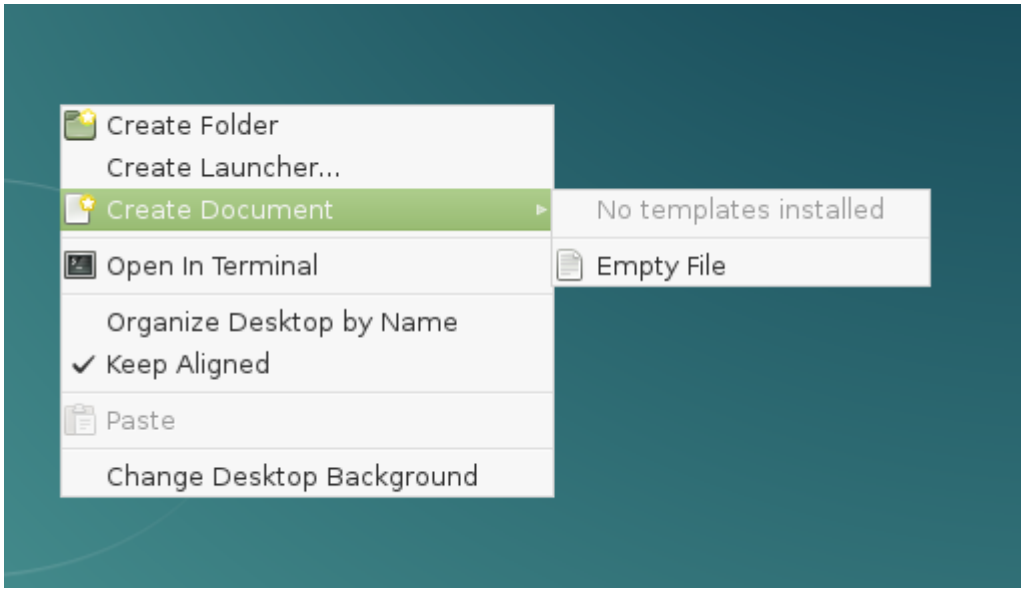
➔ Cadence Hint: Use DC sweep instead of parametric sweep whenever possible. DC sweep is extremely faster, and uses much less resources and disk space. In this question you should use DC sweep for VGS.

➔ Cadence Hint: To simulate both the short channel and the long channel devices in the same simulation run you can use parametric sweep. Define L as a parameter (L = 200n, 2u) and define W as a function of L (W = 5*L).

First launch adexl and set values of parameters.



Create a new text file



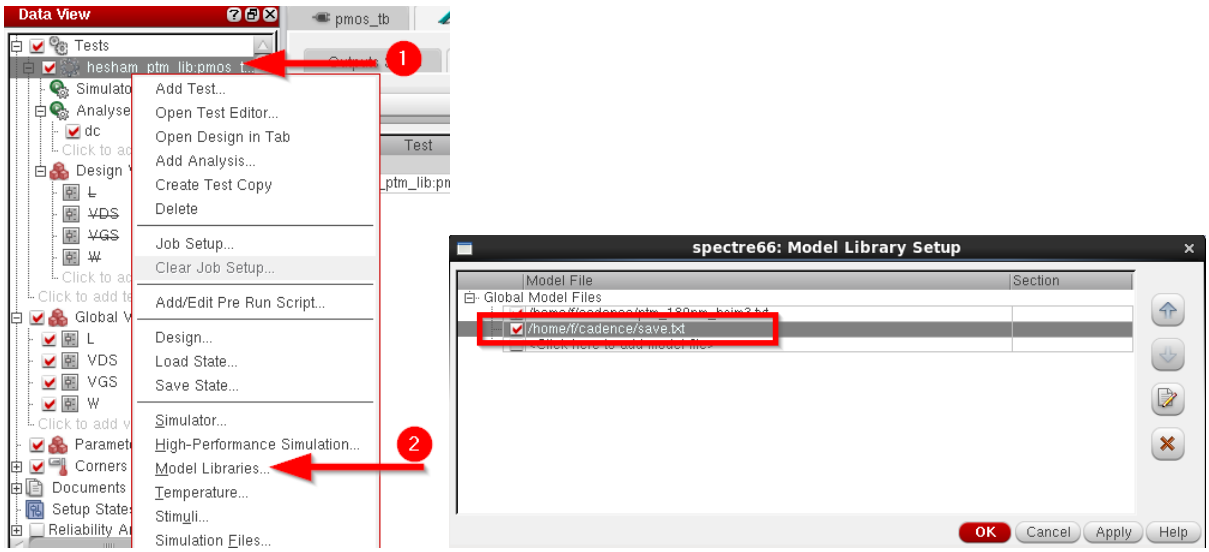
Write these commands in the file

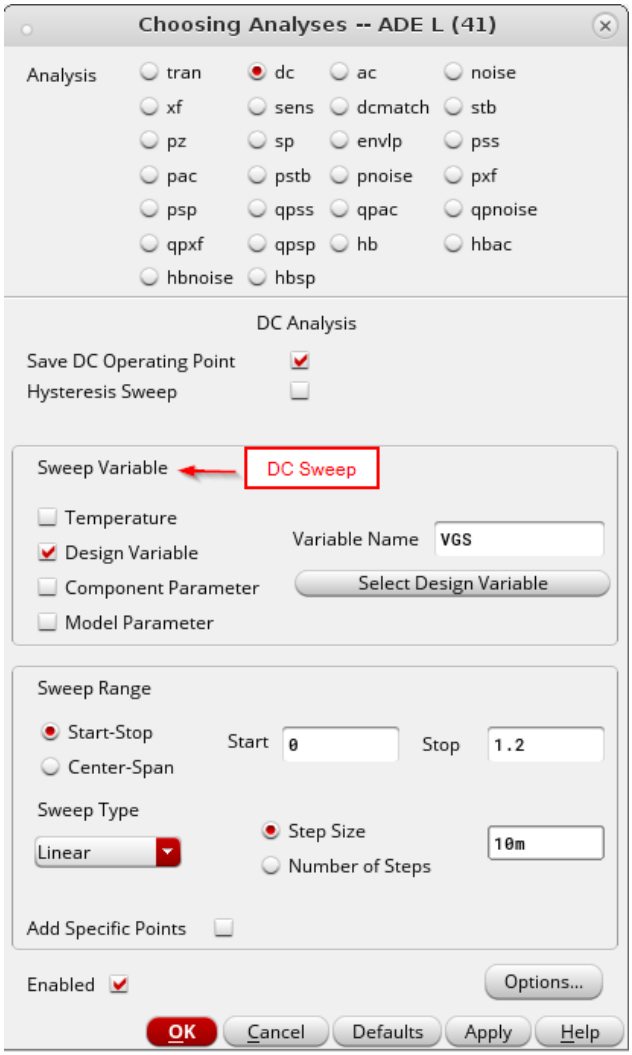
simulator lang = spectre

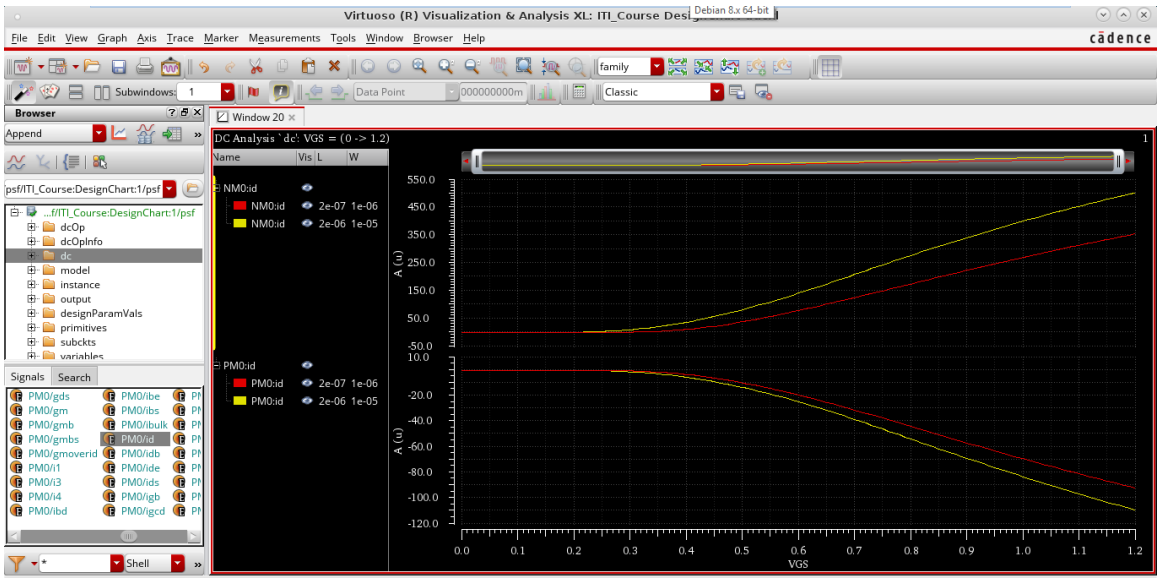
save *:oppoint sigtype=dev

Save the file and give it a name (e.g., save.txt)

Open Model Libraries and add the file you just created to the libraries.

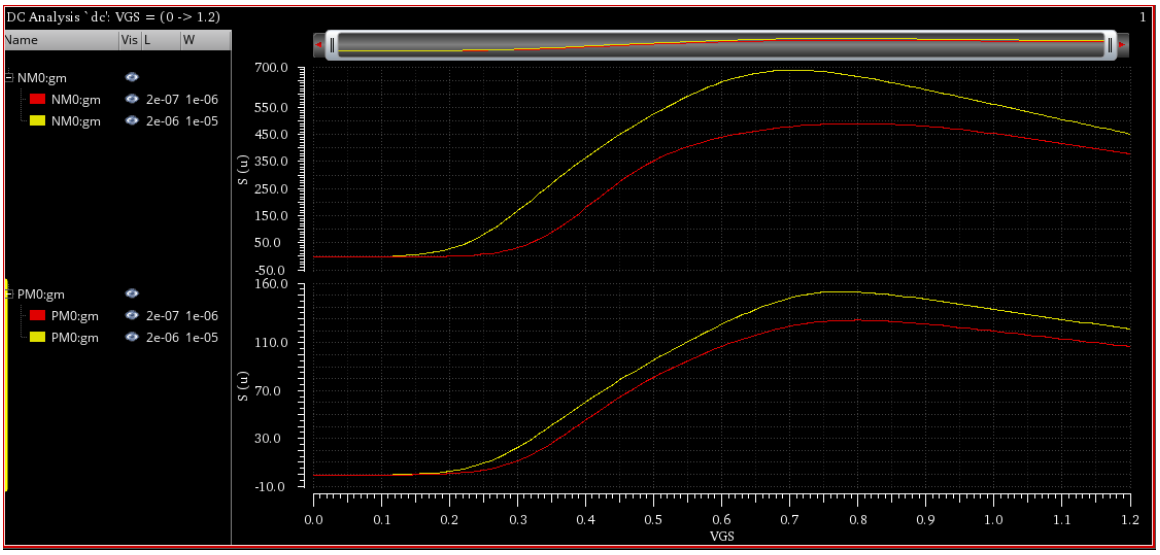






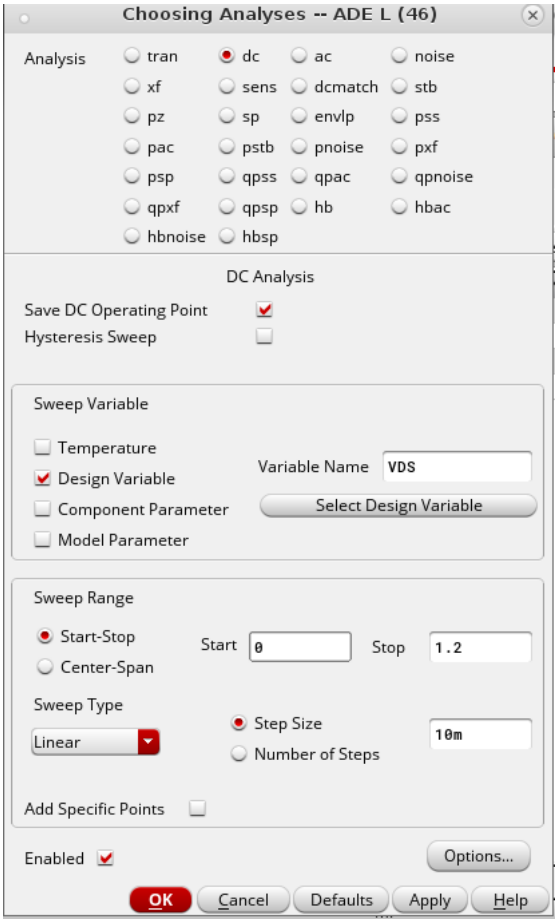
2. g_m vs VGS

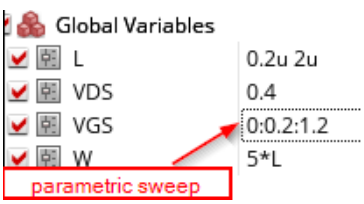
➔ Cadence Hint: In order to save gm vs DC sweep variable, create an empty text file and write the following statement (without quotes): “save *:gm sigtype=dev”. To save all OP point parameters for all transistors use (without quotes): “save *:oppoint sigtype=dev”. Add this text file in adexl (Setup -> Model Libraries).

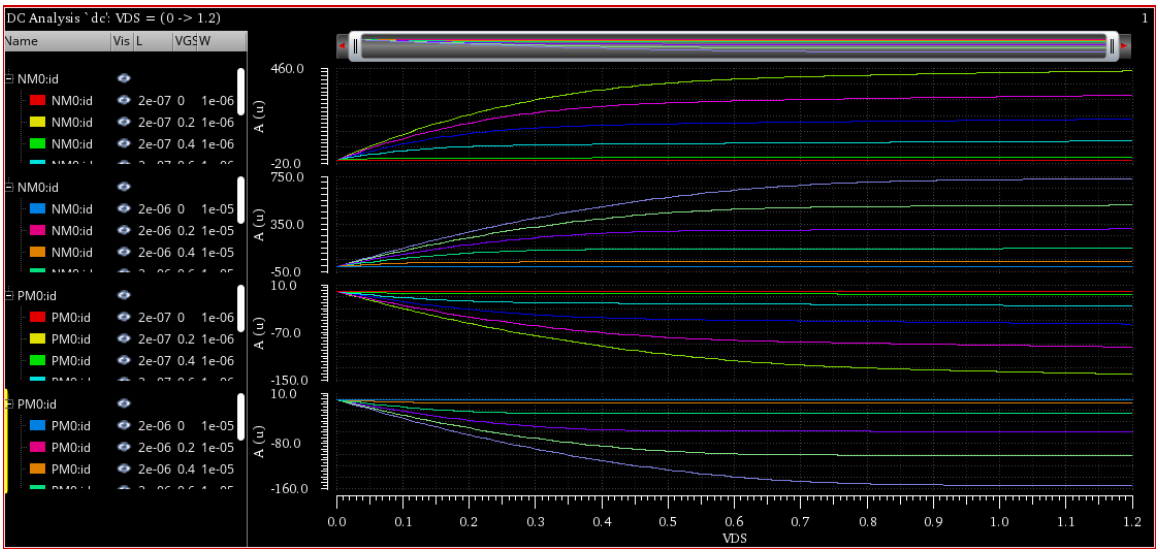


3. ID vs VDS

➔ Cadence Hint: In Mentor Eldo and Synopsys HSPICE you can do nested DC sweep (DC sweep with multiple variables) . But in Cadence Virtuoso you can use only one DC sweep variable. Thus, you should use DC sweep for the variable with fine step, i.e., the primary variable (VDS in this case), and parametric sweep for the variable with coarse step, i.e., secondary variable (VGS in this case).







4. g_m and r_o in Triode and Saturation