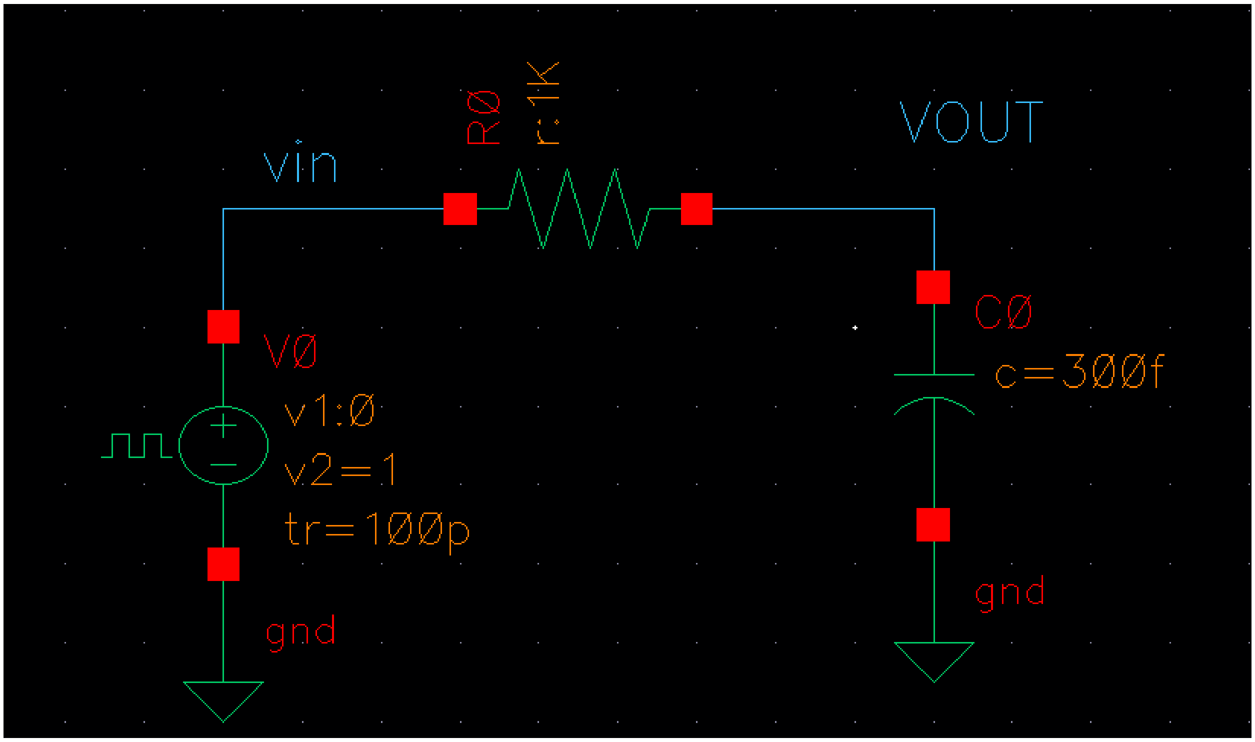
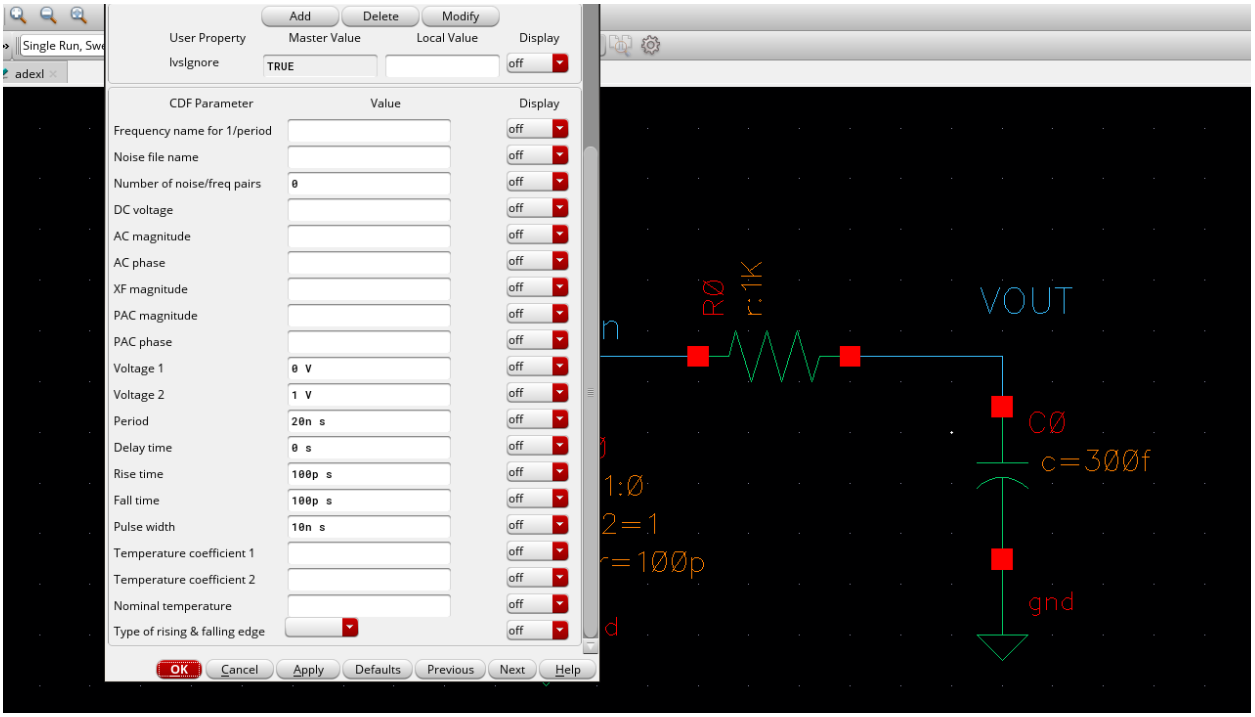
Lab 01 LPF Simulation and MOSFET Characteristics

PART 1: Low Pass Filter Simulation (LPF)

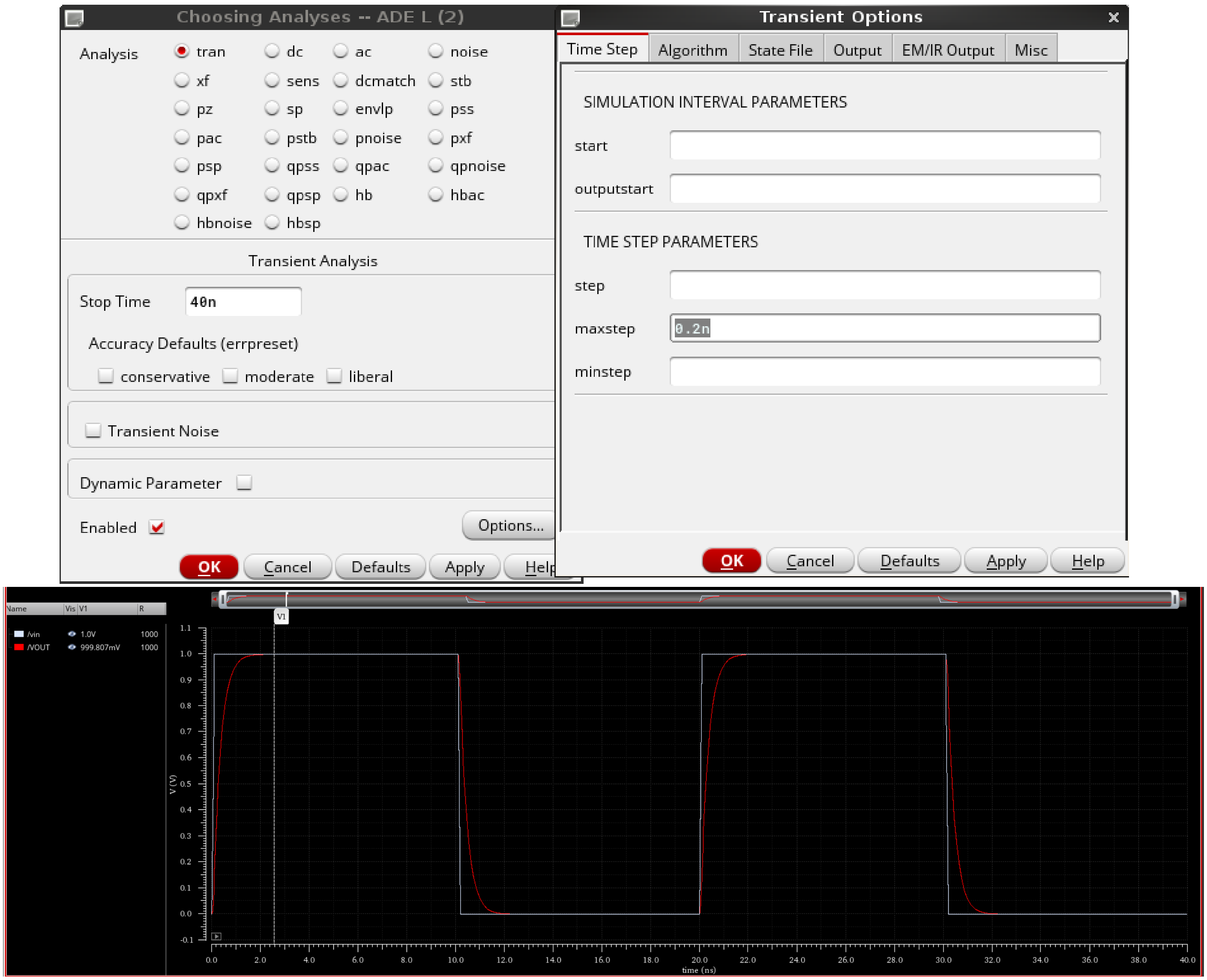
1 DESIGN A FIRST ORDER LOW PASS FILTER THAT HAS $R = 1k\Omega$ AND $0.3\ ns$ (INSTEAD OF $1\ ns$) TIME CONSTANT.



2 APPLY A SQUARE WAVE INPUT WITH $Thigh = Pulse\ Width = 10ns$, $Tclk = Period = 20ns$, AND $Trise = Tfall = 100\ p$S .

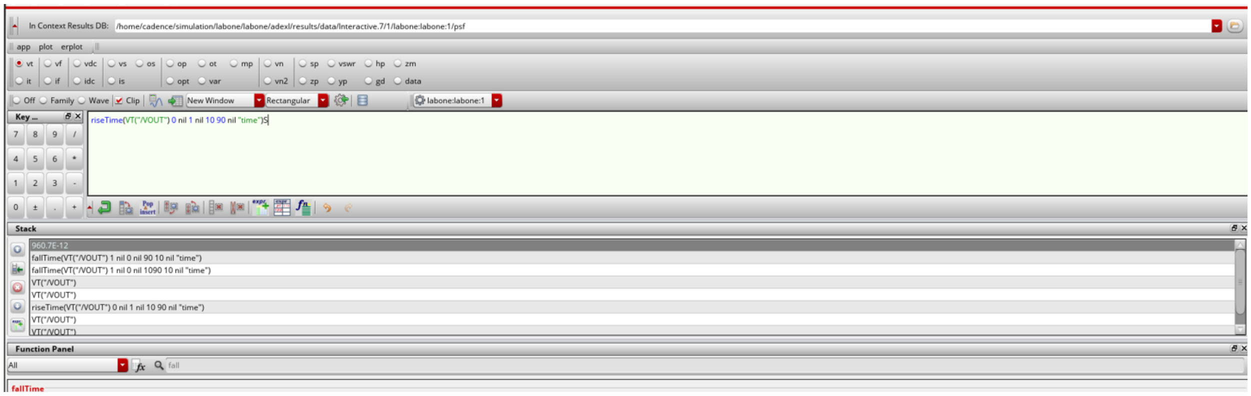


3 Report transient analysis results for two periods (use max time step = $Tclk/100$).

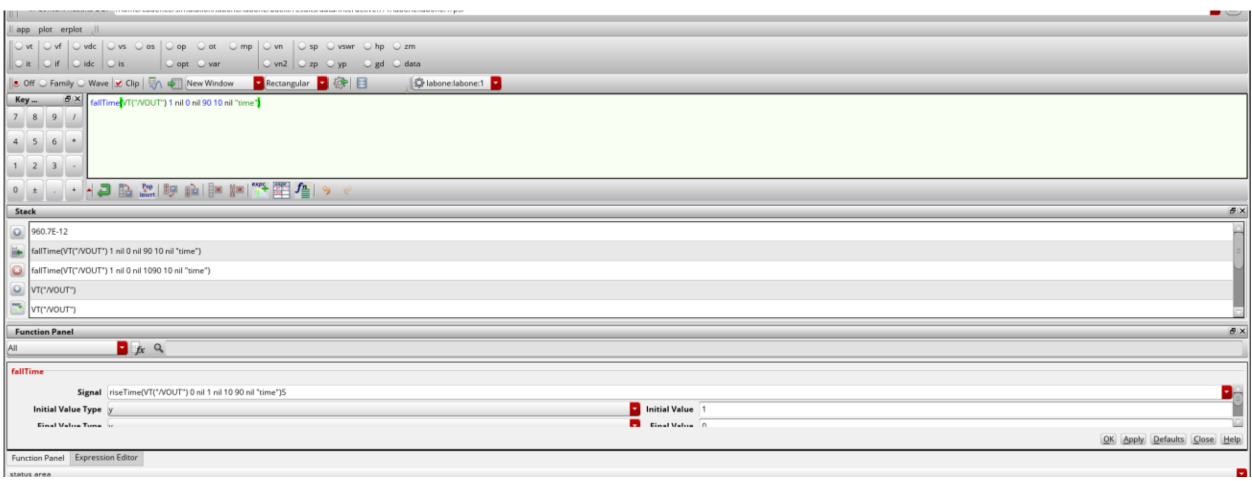


4 Calculate rise and fall time (10% to 90%) using Cadence calculator expressions. Export the expressions to ADEXL.

4.1 Rise Time



4.2 Fall Time



Test	Name	Type	Details	EvalType	Plot	Save
labone:labone:1		expr		point	☐	☐
labone:labone:1	Trise	expr	riseTime(VT("/VOUT") 0 nil 1 nil 10 90 nil "time")	point	✔	☐
labone:labone:1	Tfall	expr	fallTime(VT("/VOUT") 1 nil 0 nil 90 10 nil "time")	point	✔	☐
labone:labone:1		signal	/vin	point	✔	✔
labone:labone:1		signal	/VOUT	point	✔	✔

Test	Output	Nominal	Spec	Weight	Pass/Fail
labone:labone:1	Trise	661.8p			
labone:labone:1	Tfall	661.8p			
labone:labone:1	/vin				
labone:labone:1	/VOUT				

5 COMPARE SIMULATION WITH ANALYTICAL RESULTS IN A TABLE.

	SIM	analytical
Trise	661.8p	659.17 p
Tfall	661.8p	659.17 p

$$0.9=1-e^{-\frac{T_{90\%}}{0.3n}}\ ,\ T_{90\%} = 690.77p$$

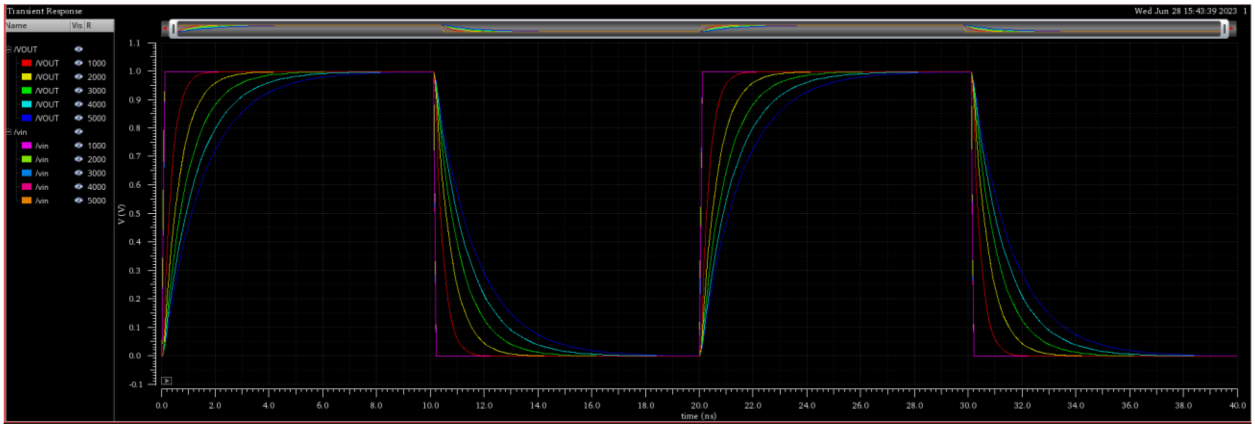
$$0.1=1-e^{-\frac{T_{10\%}}{0.3n}}\ , T_{10\%} = 31.6\text{p}$$

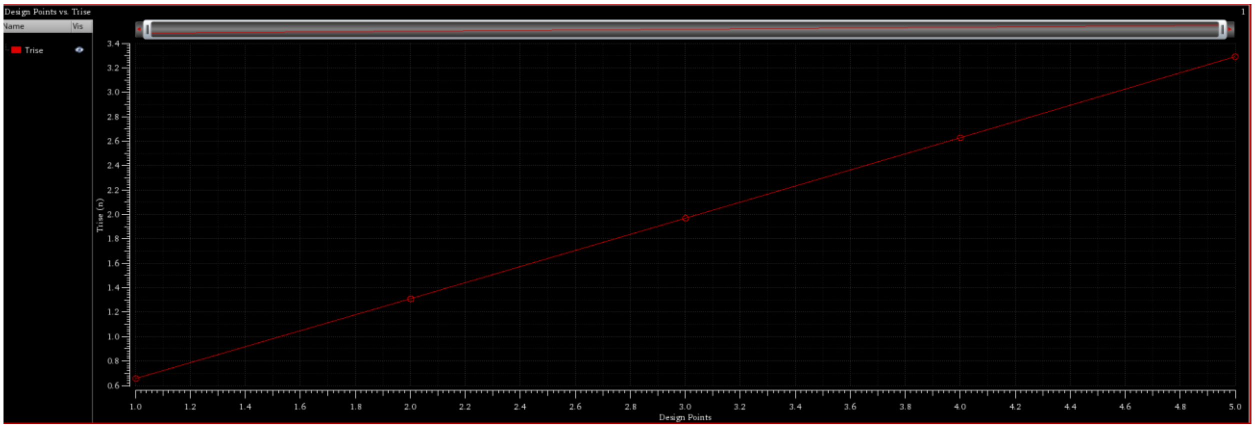
$$T_{rise} = T_{90\%} - T_{10\%} = 690.77 - 31.6 = 659.17p$$

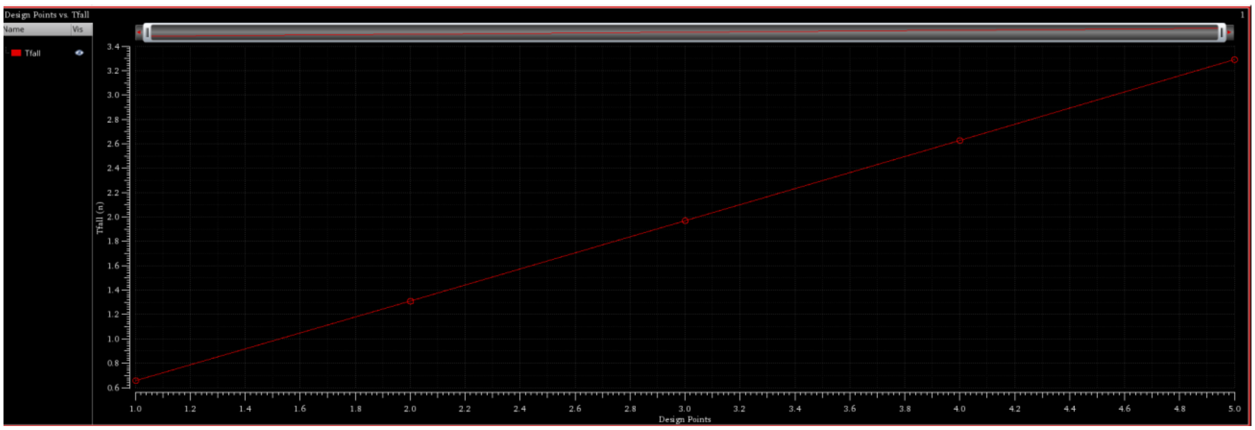
6 DO PARAMETRIC SWEEP FOR $\boldsymbol{R} = 1{:}\ 1{:}\ 5\boldsymbol{k}\Omega$. REPORT OVERLAID RESULTS. COMMENT ON THE RESULTS.

6.1

Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: R=1k						
1	labone:labone:1	Trise	661.8p			
1	labone:labone:1	Tfall	661.8p			
1	labone:labone:1	/vin				
1	labone:labone:1	/VOUT				
Parameters: R=2k						
2	labone:labone:1	Trise	1.312n			
2	labone:labone:1	Tfall	1.312n			
2	labone:labone:1	/vin				
2	labone:labone:1	/VOUT				
Parameters: R=3k						
3	labone:labone:1	Trise	1.974n			
3	labone:labone:1	Tfall	1.974n			
3	labone:labone:1	/vin				
3	labone:labone:1	/VOUT				
Parameters: R=4k						
4	labone:labone:1	Trise	2.632n			
4	labone:labone:1	Tfall	2.632n			
4	labone:labone:1	/vin				
4	labone:labone:1	/VOUT				
Parameters: R=5k						
5	labone:labone:1	Trise	3.294n			
5	labone:labone:1	Tfall	3.294n			
5	labone:labone:1	/vin				
5	labone:labone:1	/VOUT				



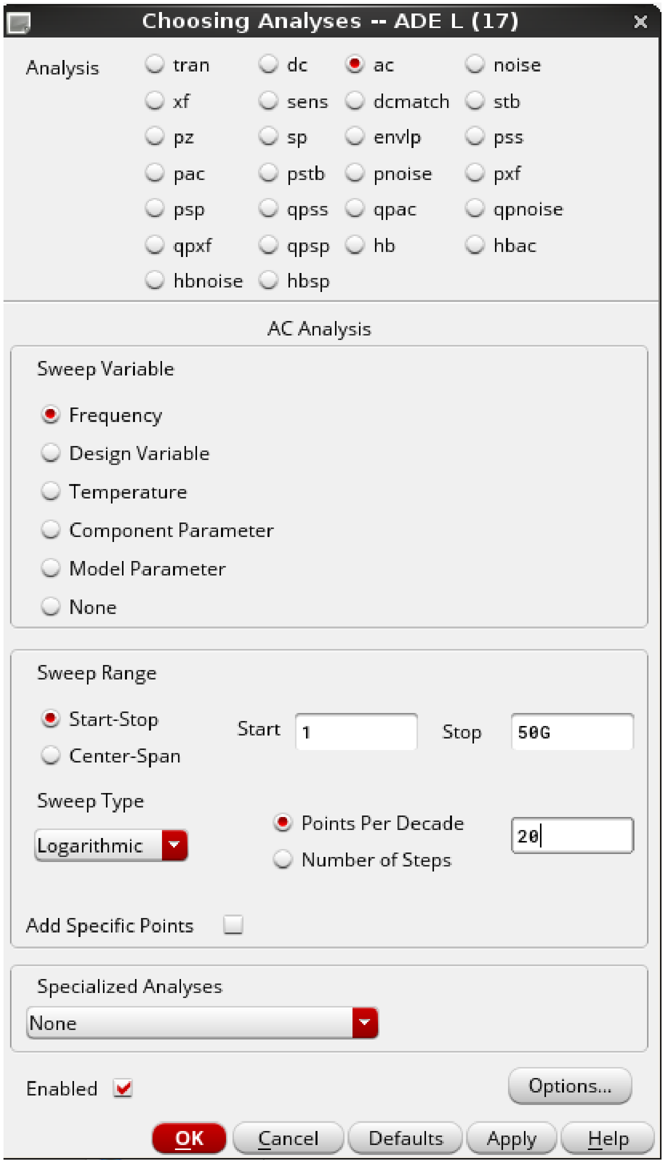


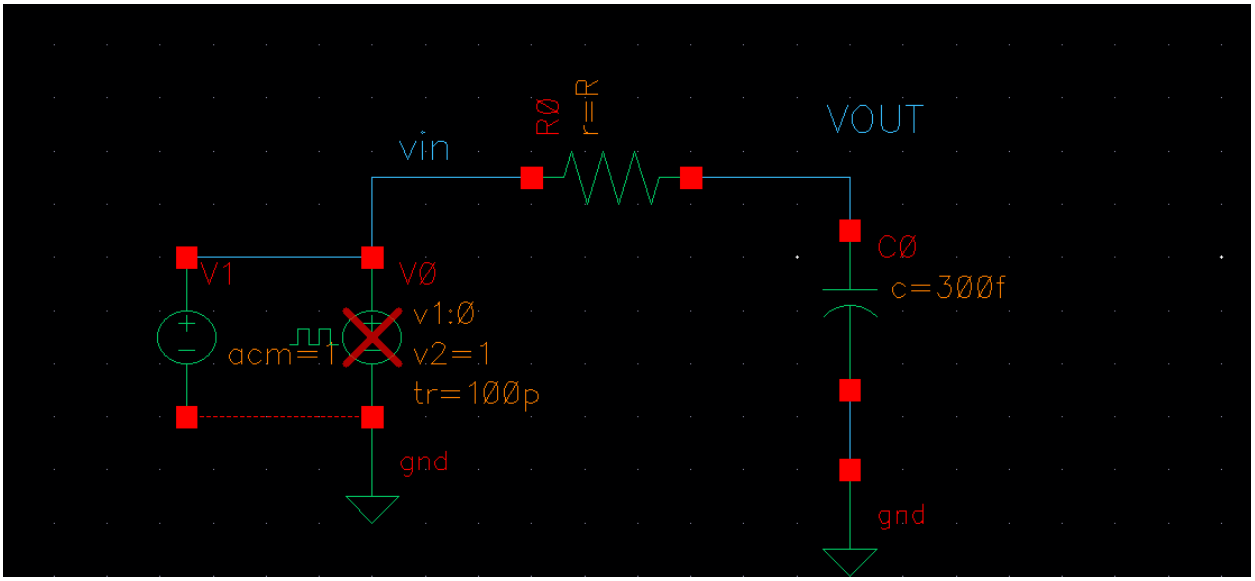


6.2 COMMENT :

As R increases the time constant of the filter increases $\tau = RC$.

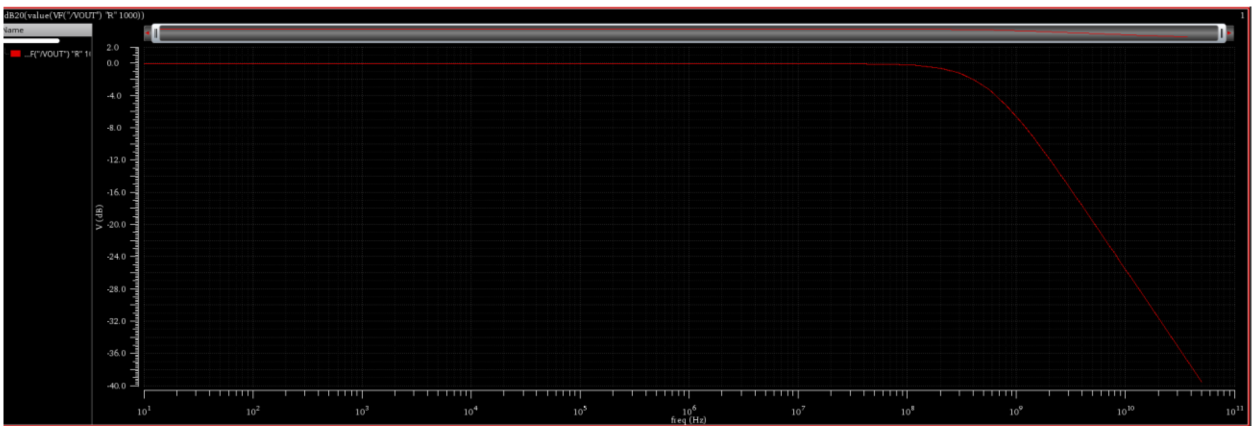
AC ANALYSIS


Choosing Analyses -- ADE L (17)
Analysis
tran
dc
ac
noise
xf
sens
dcmatch
stb
pz
sp
envlp
pss
pac
pstb
pnoise
pxf
psp
qpss
qpac
qpnoise
qpxf
qpsp
hb
hbac
hbnoise
hbsp
AC Analysis
Sweep Variable
Frequency
Design Variable
Temperature
Component Parameter
Model Parameter
None
Sweep Range
Start-Stop
Center-Span
Start
1
Stop
50G
Sweep Type
Logarithmic
Points Per Decade
Number of Steps
20
Add Specific Points
Specialized Analyses
None
Enabled
Options...
OK
Cancel
Defaults
Apply
Help

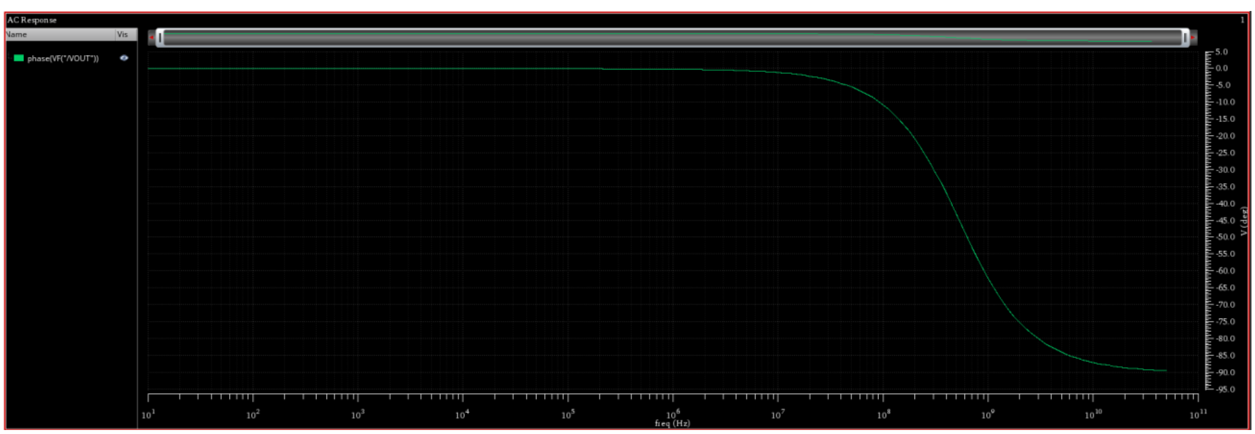


1 REPORT BODE PLOT (MAGNITUDE AND PHASE) FOR THE PREVIOUS LPF.

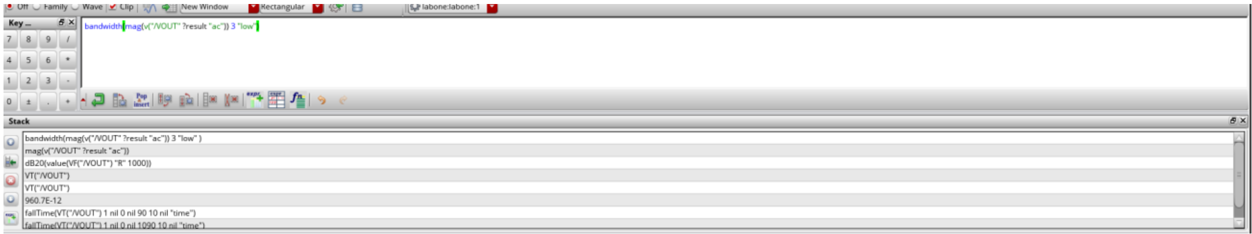
1.1 MANGNITUDE

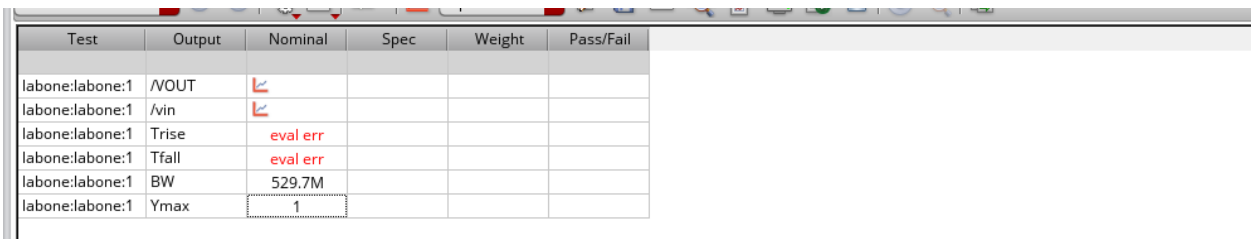


1.2 PHASE



2 CALCULATE DC GAIN AND 3DB BANDWIDTH USING CADENCE CALCULATOR EXPRESSIONS. EXPORT THE EXPRESSIONS TO ADEXL.





Test	Output	Nominal	Spec	Weight	Pass/Fail
labone:labone:1	/VOUT				
labone:labone:1	/vin				
labone:labone:1	Trise	eval err			
labone:labone:1	Tfall	eval err			
labone:labone:1	BW	529.7M			
labone:labone:1	Ymax	1			

there is no transience, so Trise & Tfall give errors.

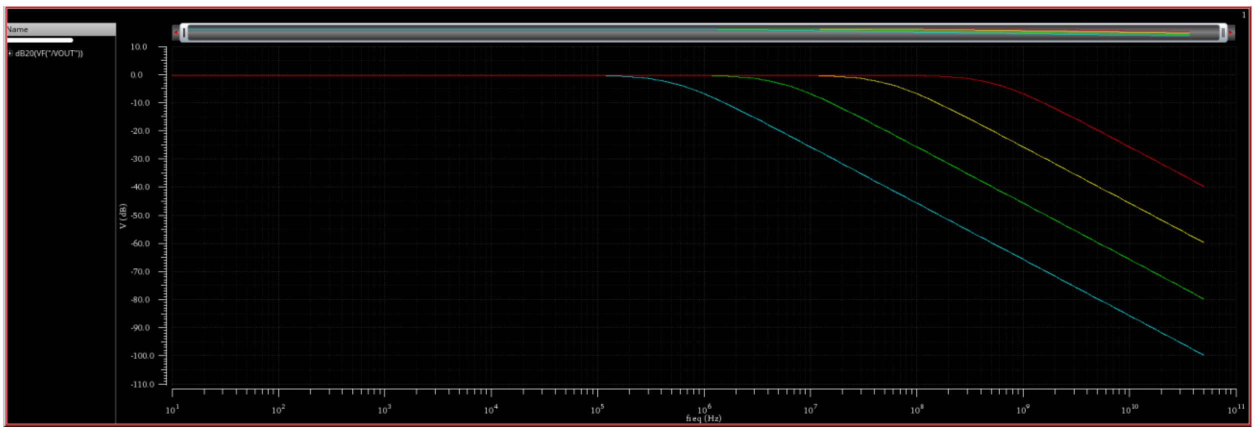
3 COMPARE SIMULATION WITH ANALYTICAL RESULTS IN A TABLE

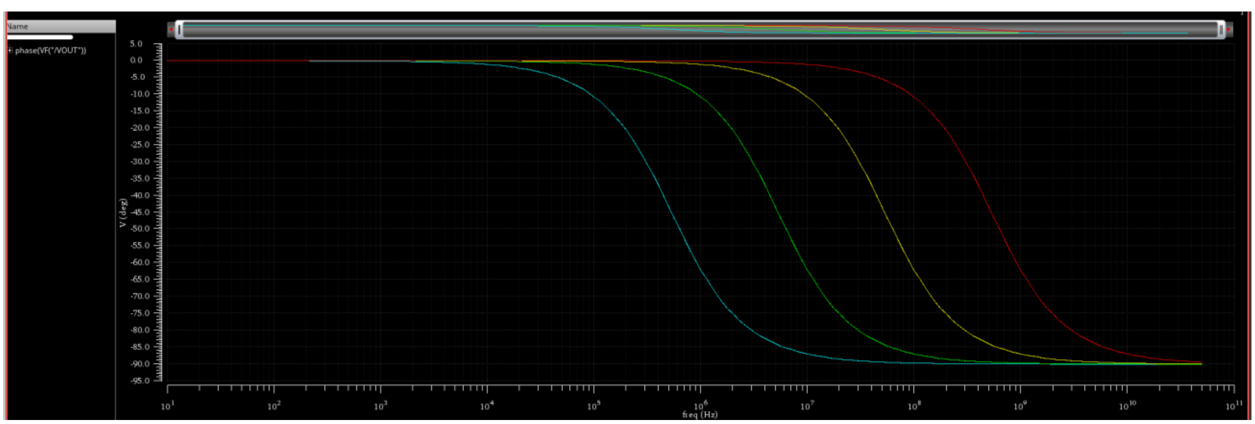
	SIM	Analytical
BW	529.7M	$\frac{1}{0.3*10^{-9}*2\pi} = 530.5M$
DCgain	1	1

4 DO PARAMETRIC SWEEP FOR $R = 1,10,100,1000k\Omega$. REPORT OVERLAID RESULTS. COMMENT ON THE RESULTS

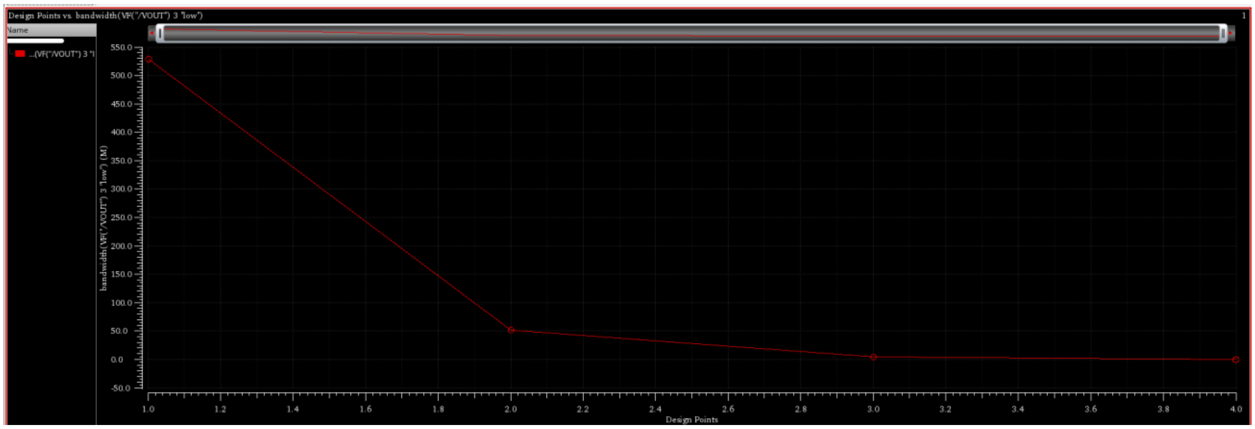
4.1

Point	Test	Output	Nominal	Spec	Weight	Pass/Fail
Parameters: R=1k						
1	labone:labone:1	/VOUT				
1	labone:labone:1	/vin				
1	labone:labone:1	Trise	eval err			
1	labone:labone:1	Tfall	eval err			
1	labone:labone:1	BW	529.7M			
1	labone:labone:1	Ymax	1			
Parameters: R=10k						
2	labone:labone:1	/VOUT				
2	labone:labone:1	/vin				
2	labone:labone:1	Trise	eval err			
2	labone:labone:1	Tfall	eval err			
2	labone:labone:1	BW	52.97M			
2	labone:labone:1	Ymax	1			
Parameters: R=100k						
3	labone:labone:1	/VOUT				
3	labone:labone:1	/vin				
3	labone:labone:1	Trise	eval err			
3	labone:labone:1	Tfall	eval err			
3	labone:labone:1	BW	5.297M			
3	labone:labone:1	Ymax	1			
Parameters: R=1M						
4	labone:labone:1	/VOUT				
4	labone:labone:1	/vin				
4	labone:labone:1	Trise	eval err			
4	labone:labone:1	Tfall	eval err			
4	labone:labone:1	BW	529.7k			
4	labone:labone:1	Ymax	1			





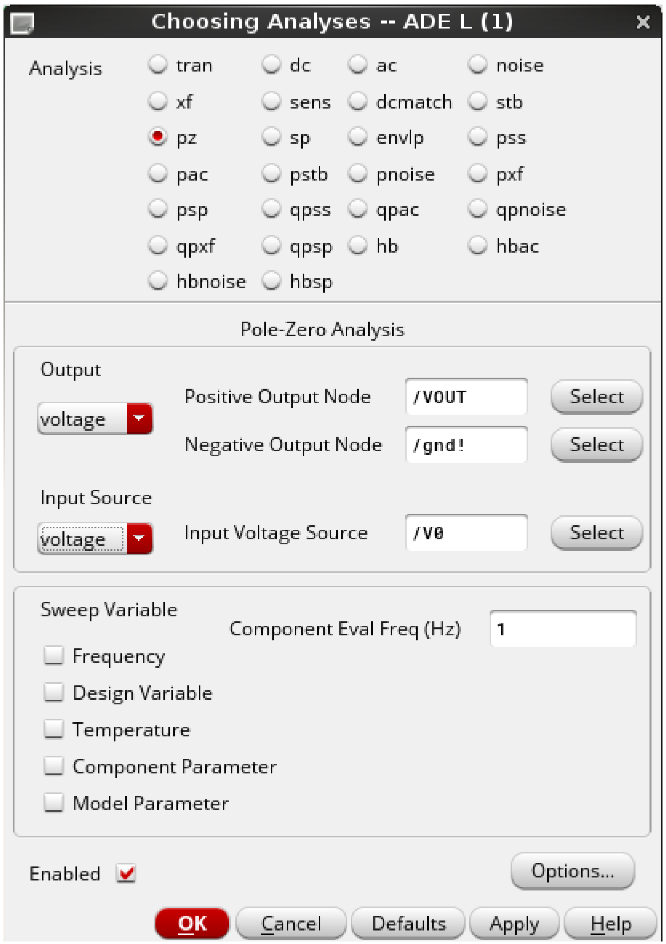
4.2 COMMENT

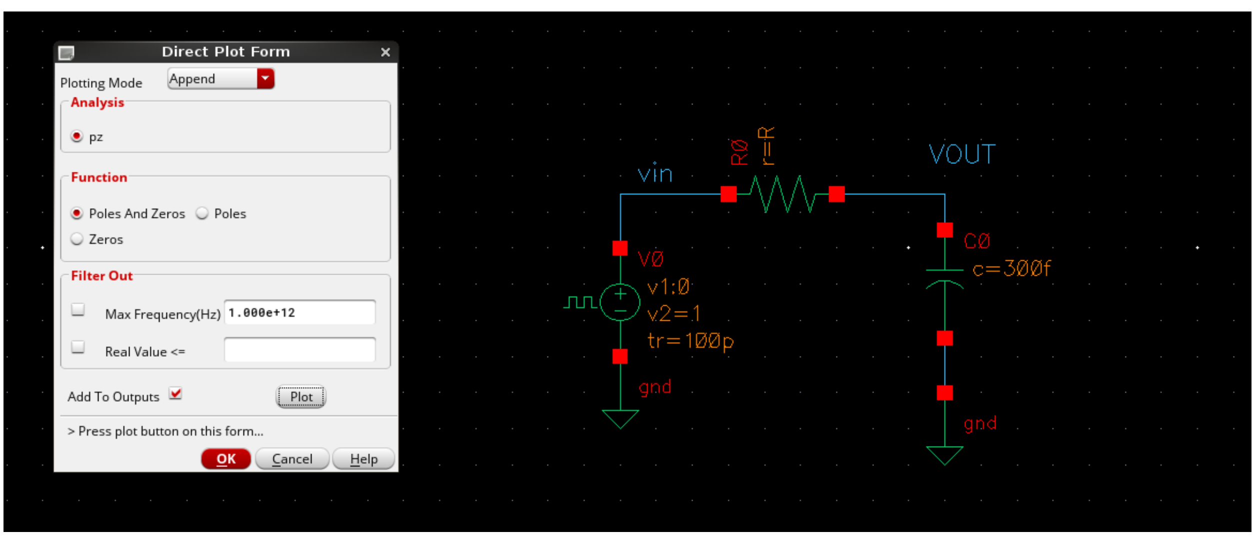


As R increases Bandwidth decreases as BW=$\frac{1}{2\pi RC}$ but gain is the same.

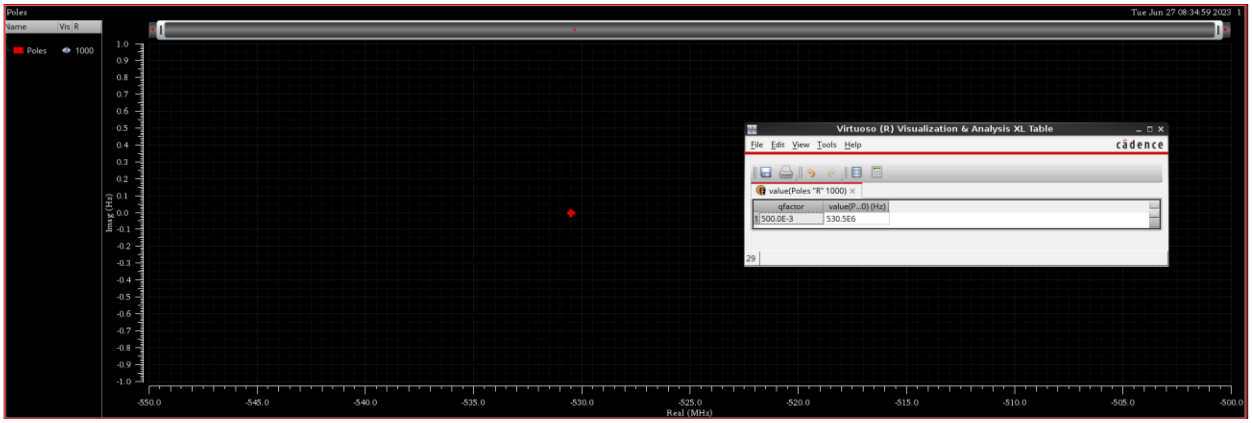
[OPTIONAL] POLE ZERO ANALYSIS

1 REPORT POLE ZERO ANALYSIS RESULTS.





labone:labone:1	Poles				
labone:labone:1	Zeros	eval err			



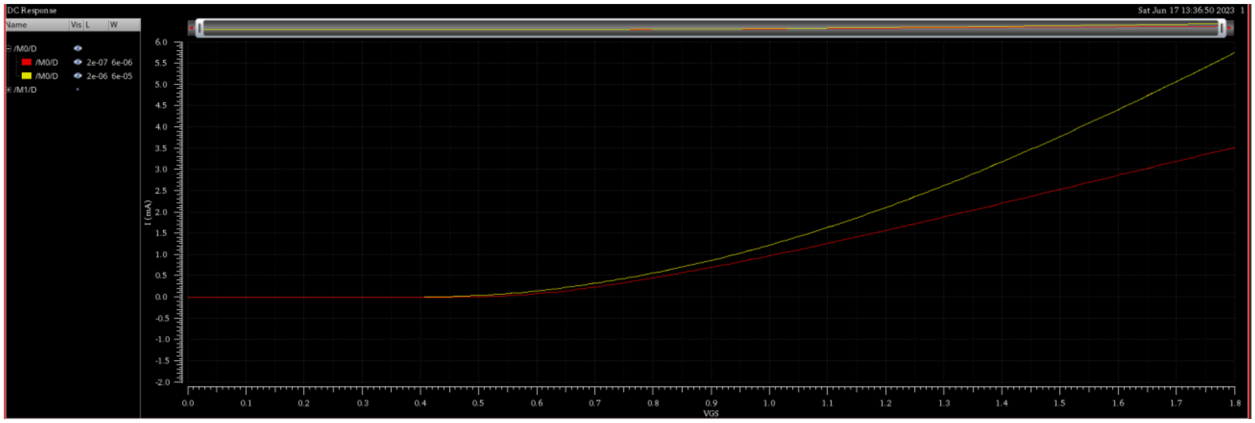
The pole frequency is 530.5M but the bandwidth calculated from AC analysis is 529.7m, so the pole frequency is more accurate and closer to the analytical solution which is also 530.5M.

PART 2: MOSFET Characteristics

1 ID vs VGS

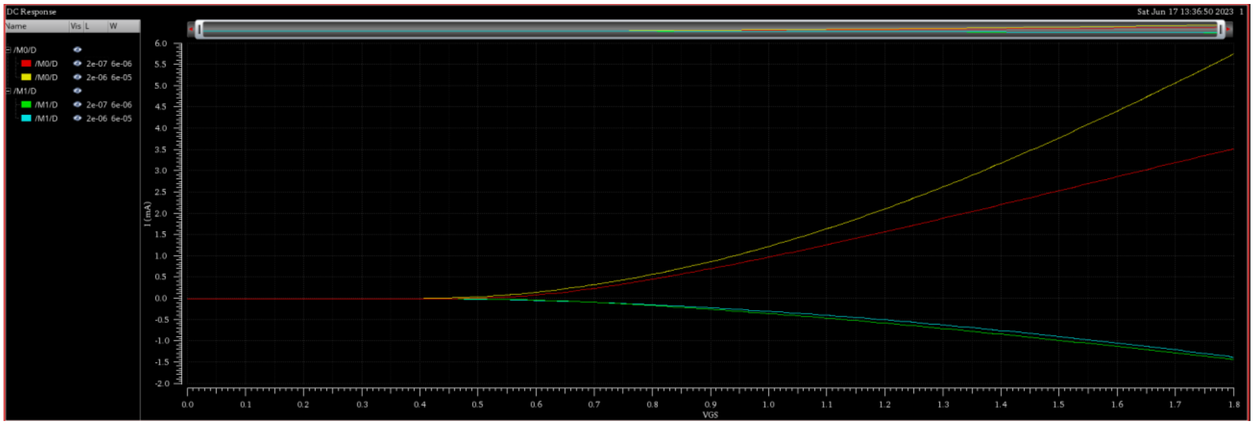
1.1 Plot $ID - VGS$ characteristics for NMOS and PMOS devices.

1.1.1 NMOS Small channel & Long channel



1.1.2 PMOS Small channel & Long channel

1.1.3 NMOS with Pmos



1.2 COMMENT ON THE DIFFERENCES BETWEEN SHORT CHANNEL AND LONG CHANNEL RESULTS.

1.2.1 Which one has higher current? Why?

Long channel has higher current, because of mobility degradation effect (increase of vertical electric field) & velocity saturation effect (increase of lateral electric field) when decreasing the channel length the electric field becomes very large to become critical electric field, so the velocity also saturate with specific Vds_{sat} even before the Pinch off saturation (Vov) , so it affects the small channel current to become lower as it saturates quicker .

1.2.2 Is the relation linear or quadratic? Why?

In long channel it is quadratic (square law is applicable), but in short channel it is more like a linear after the effect happens with $\boldsymbol{V}ds_{sat}$ (VGS= VDSsat+Vth) because of velocity saturation effect, as VDS is saturated so the relation between ID and Vov (VGS-VTH) becomes linear.

1.3 COMMENT ON THE DIFFERENCES BETWEEN NMOS AND PMOS :

1.3.1 Which one has higher current? Why?

NMOS has higher current because electrons has higher mobility than holes.

1.3.2 What is the ratio between NMOS and PMOS currents at VGS = VDD?

From calculator :

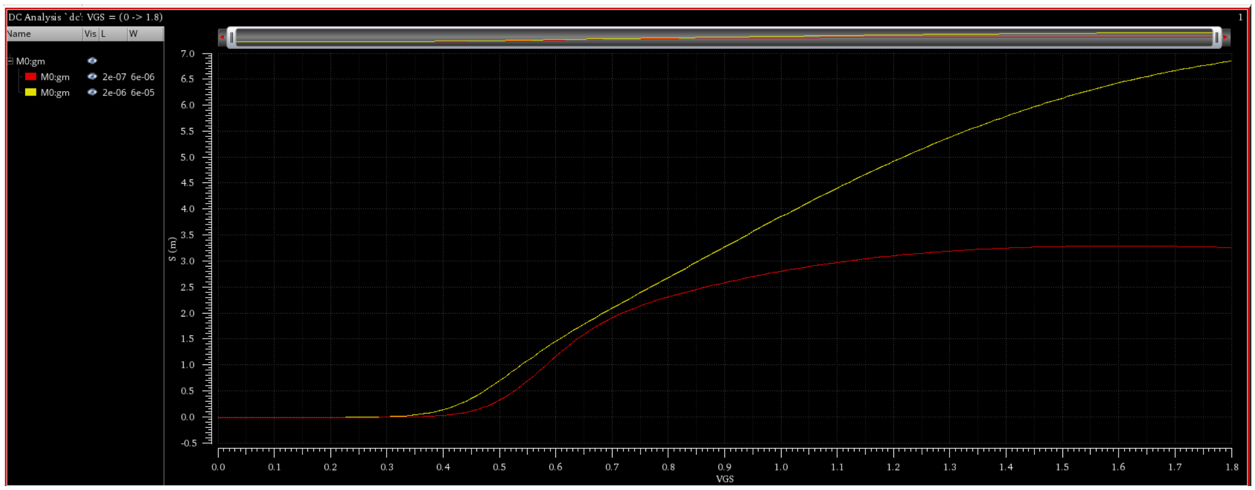
	NMOS	PMOS	RATIO
SHORT CHANNEL	3.532E-3	1.4269E-3	2.475
LONG CHANNEL	5.755E-3	1.373E-3	4.19

1.3.3 Which one is more affected by short channel effects?

NMOS is more affected because it has higher mobility than PMOS so it reaches velocity saturation faster, $\epsilon = \frac{\boldsymbol{vsat}}{\boldsymbol{\mu}} = \frac{\boldsymbol{Vsat}}{\boldsymbol{L}}$, $\boldsymbol{Vsat} = \frac{\boldsymbol{L*vsat}}{\boldsymbol{\mu}}$.

2 gm VS VGS

2.1 PLOT gm VS VGS FOR NMOS DEVICE.



2.2 COMMENT ON THE DIFFERENCES BETWEEN SHORT CHANNEL AND LONG CHANNEL RESULTS.

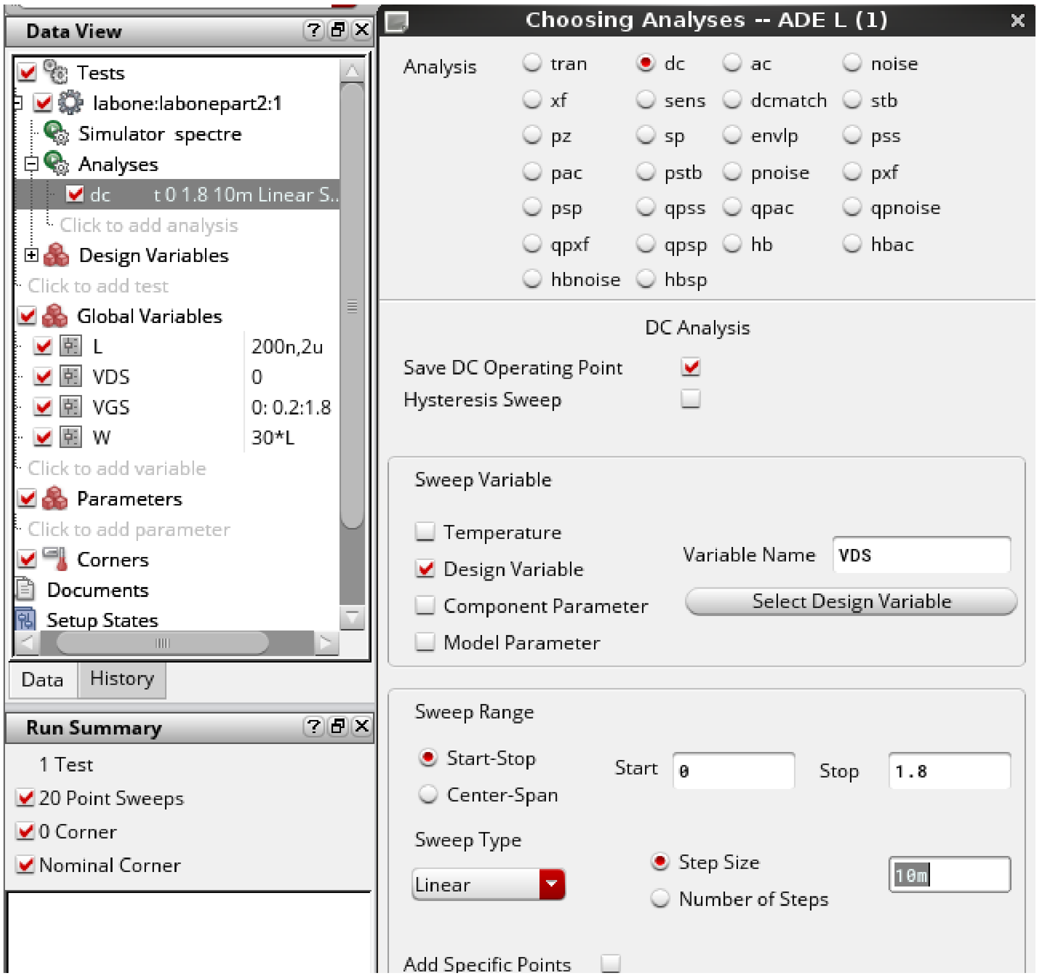
2.2.1 Does gm increase linearly? Why?

not ideally linear, but It kind of increasing linearly because the characteristic of Id vs vgs is quadratic and gm is the slope of it .

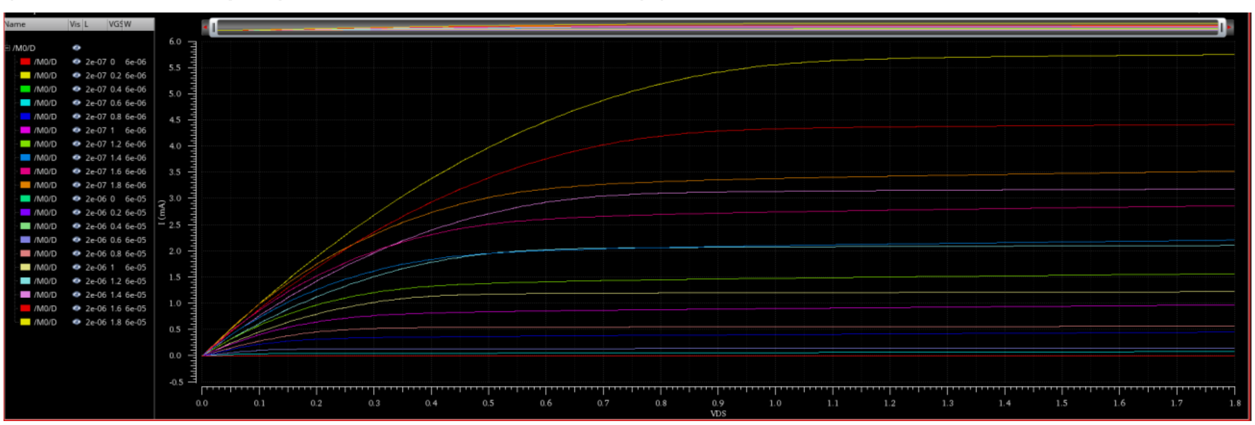
2.2.2 Does gm saturate? Why?

It saturates in short channel because the (id vs Vgs) becomes liner because of velocity saturation, mobility degradation and gm is the slope of this linear characteristic (gm is constant) but it doesn't saturate in large channel model.

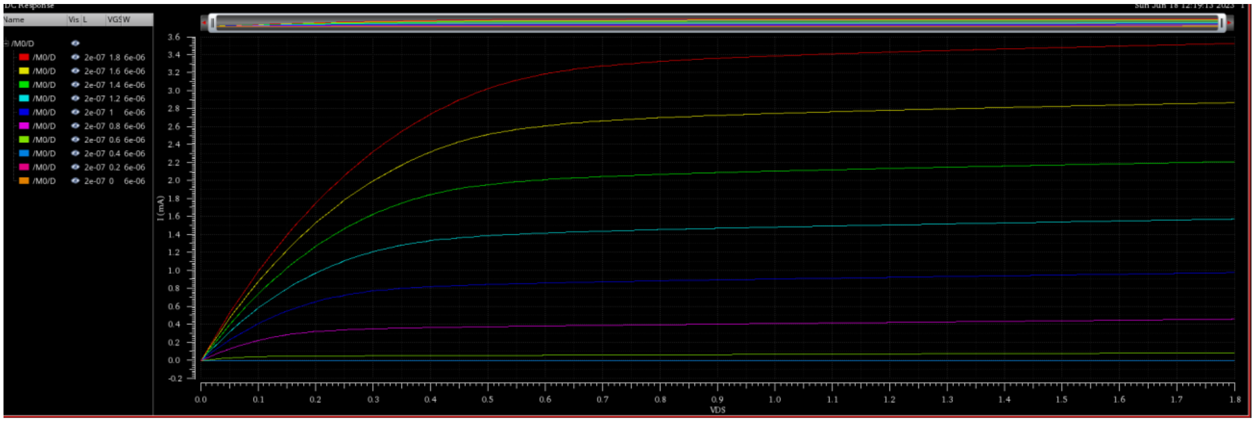
3 ID vs VDS



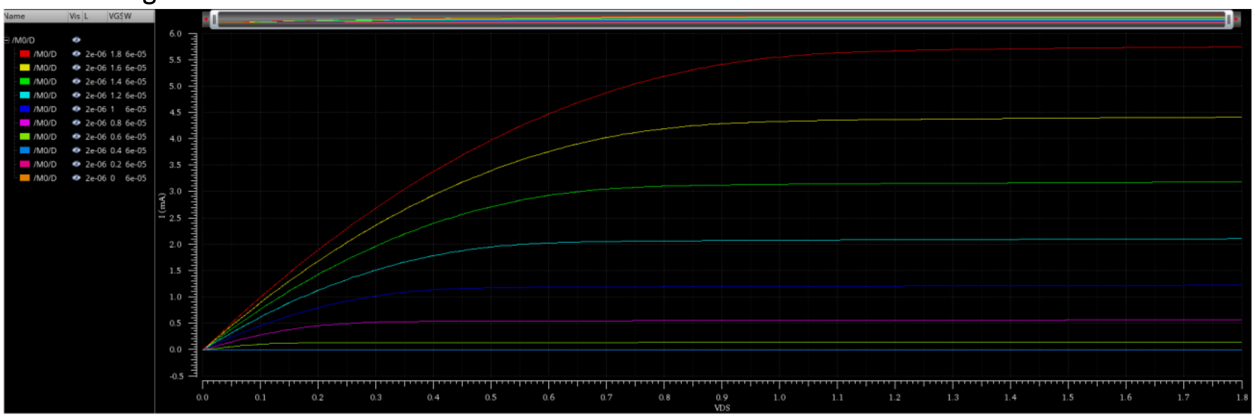
3.1 Plot $ID - VDS$ characteristics for NMOS device



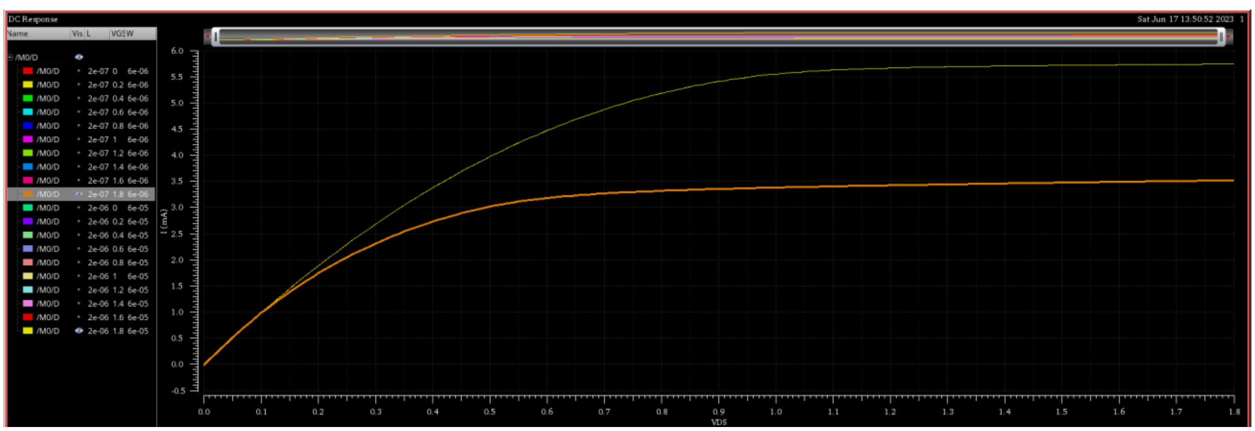
3.1.1 Short channel device:



3.1.2 Long channel device:



3.2 COMMENT ON THE DIFFERENCES BETWEEN SHORT CHANNEL AND LONG CHANNEL RESULTS.



Small channel current vs long channel current under same VGS

3.2.1 Which one has higher current? Why?

Long channel has higher current, because of velocity saturation(increase lateral electric field) and mobility degradation (increase vertical electric field which leads to decrease mobility) affect small channel current to become less & also ID increases with VGS in short and long channel, so Long channel with highest VGS has the highest current.

3.2.2 Which one has higher slope in the saturation region? Why?

small channel current has higher slope because of DIBL & channel length modulation effect as it has higher **λ** because when L is small the pinch off point shift effect when increasing Vds more than Vov is higher than long channel case as Leff clearly becomes less in short channel case, so it has smaller r0 .