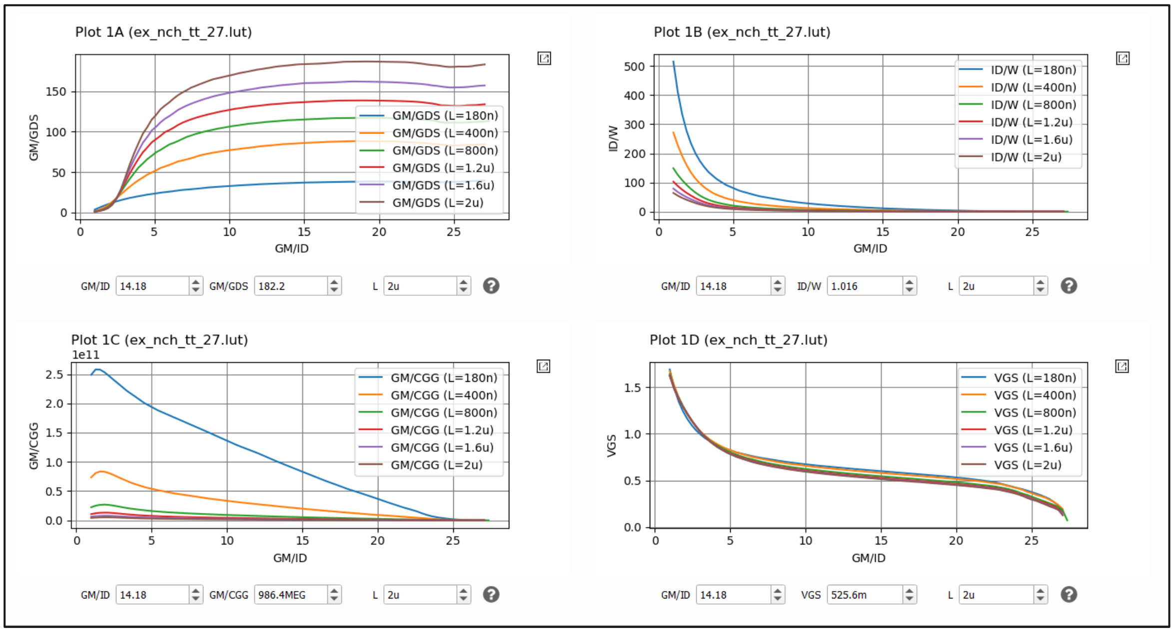
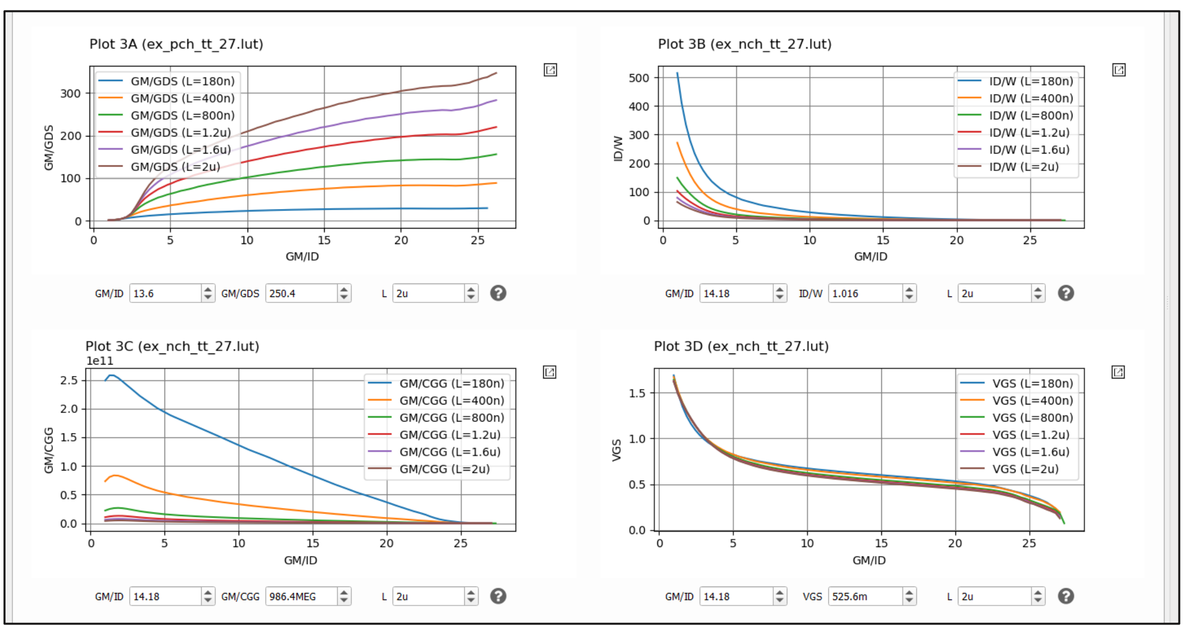
Lab 11 (Mini Project 02)

Part1: gm/id Design chart

Nmos



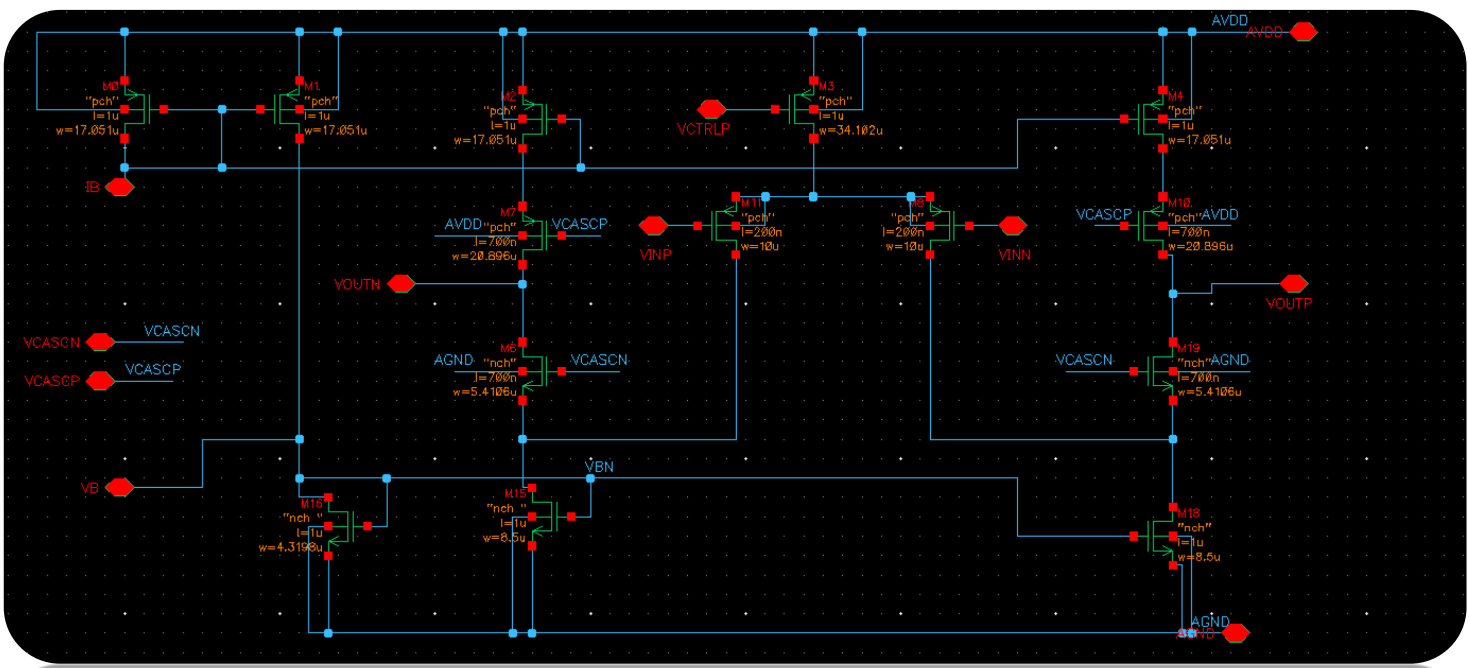
Pmos



Part2: OTA Design

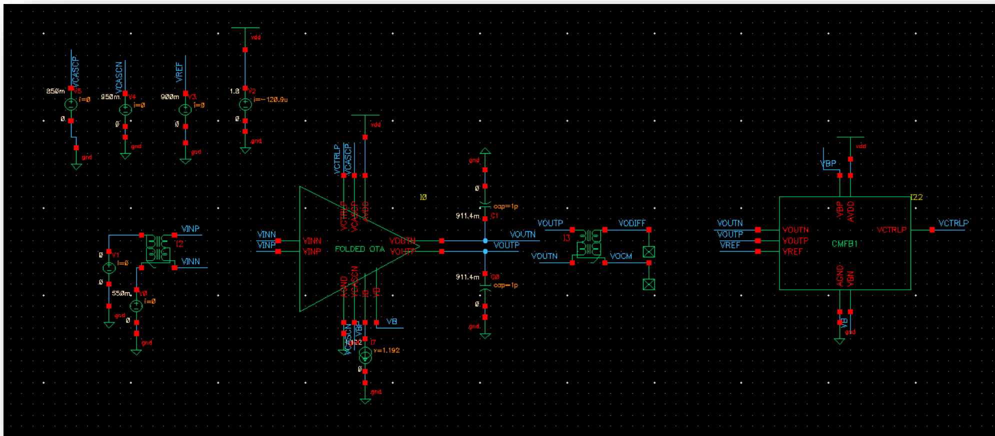
Parameter	Gm/id	id	L	W	VGS	V*
M8&M11	17	20u	0.2u	10u	572.78m	118.39m
M0&M1&M2&M4	10	20u	1u	17.051u	609.12m	201m
M3	10	40u	1u	34.102u	609.12m	201m
M7&M10	15	20u	0.7u	20.895u	649.3m	131m
M6&M19	15	20u	0.7u	5.4106u	643.2m	134.25m
M15&,18	10	40u	1u	8.5u	614m	200m
M16	10	20u	1i	4.32u	615m	200.76m

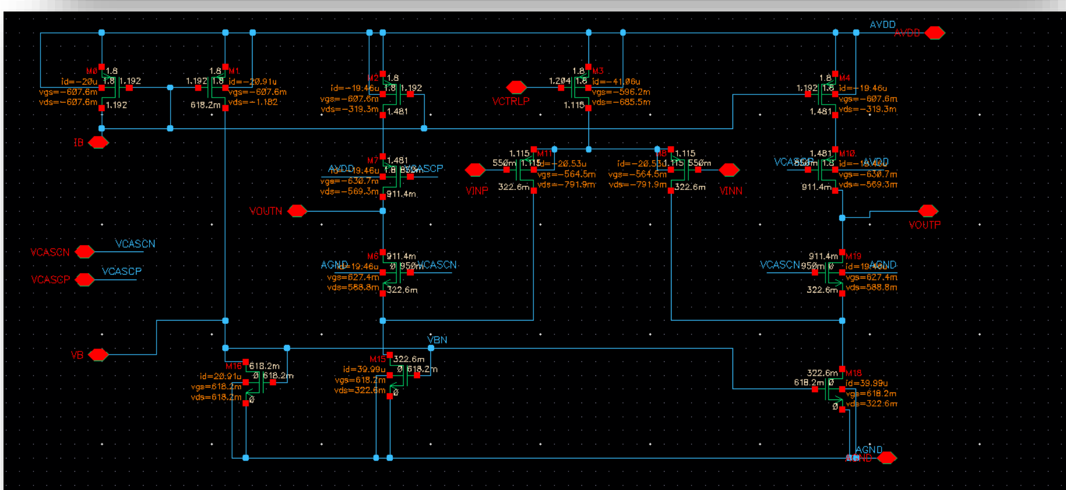
- **gm/id of input pair = 17 instead of 15 , L of cascade = 0.7 instead of 0.5 to meet specs.**

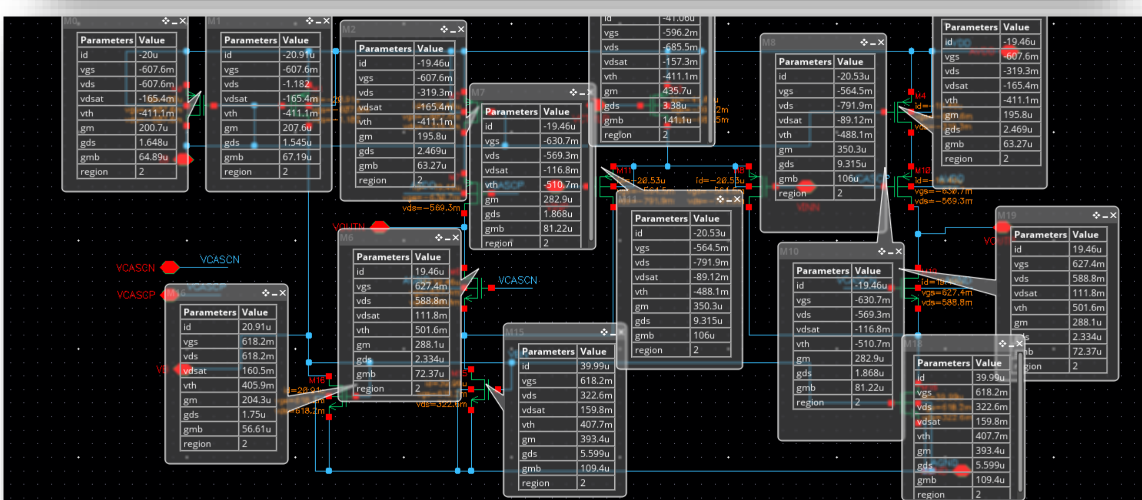


PART 3: Open-Loop OTA Simulation (Behavioral CMFB)

1) Schematic of the OTA and bias circuit with DC node voltages:







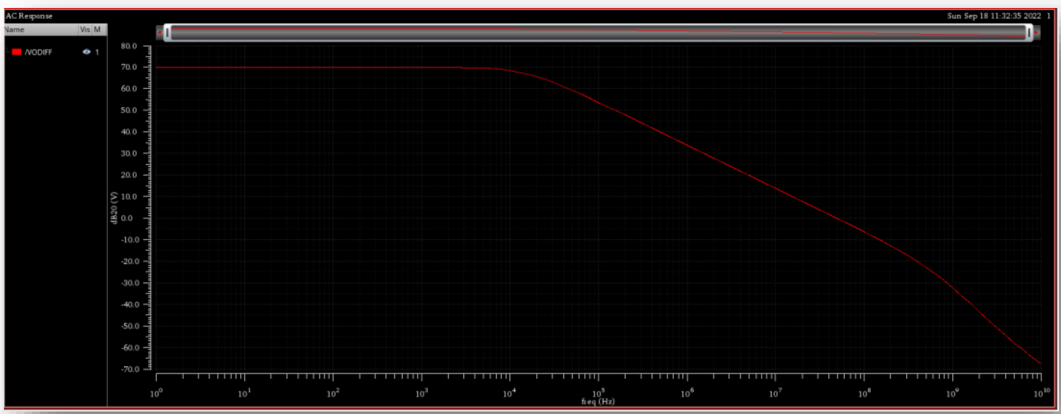
- **VOCM=911.4m**
- **VCTRLP**

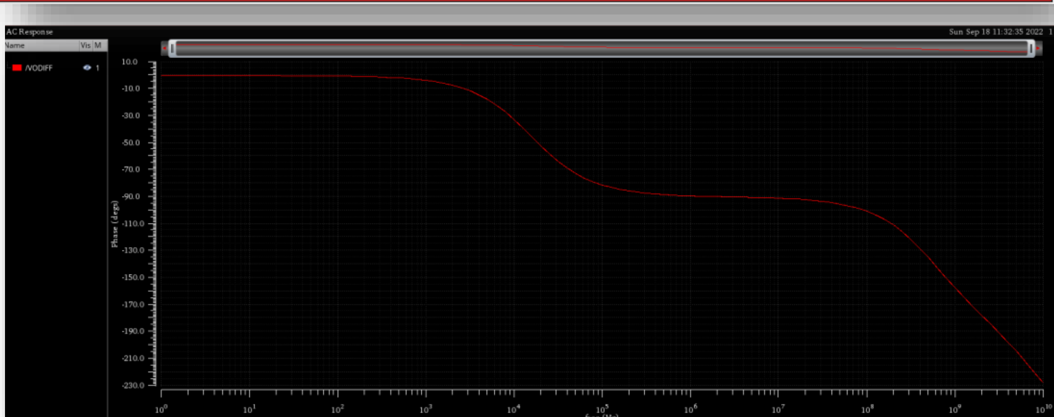
v("/VCTRLP" ?result "dcOp")-v("/VE

	M	v("/VCT...p") (V)
1	1.000	11.42E-3

- **Relation: they exactly equal because we use VCCS with gain=1**

2) Diff small signal ccs:





Test	Output	Nominal
lab11:TB:1	/VODIFF	
lab11:TB:1	ymax(mag(VF("/VODIFF")))	3.214k
lab11:TB:1	dB20(ymax(mag(VF("/VODIFF...	70.14
lab11:TB:1	gainBwProd(VF("/VODIFF"))	50.06M
lab11:TB:1	unityGainFreq(VF("/VODIFF"))	49.89M
lab11:TB:1	phaseMargin(VF("/VODIFF"))	84.64

- ## Hand Anaalysis

Gain= GM8*ROUT

ROUT=$ro10 * (ro4(gm10 + gmb10) + 1)//ro19 * ((gm19 + gmb19)(ro18//ro1)$+1)=79.48M//10.78M=9.492M

Gain=9.492M*350.3u=3.325k

Gain(db)=70.436

Bandwidth=$\frac{1}{2\pi * Rout * CL}$ =16.77k

GBW=16.77k*3.325k=55.76M

UGF=55.76M

PM=90- $tan^{-1}\left(\frac{wu}{wp2}\right) = 90 - tan^{-1}\left(\frac{wu}{\frac{gm6+gmb6}{(css6+cdd11+cdd15)}}\right) = 90 - tan^{-1}(\frac{50M}{3.37G}) = 89.06$

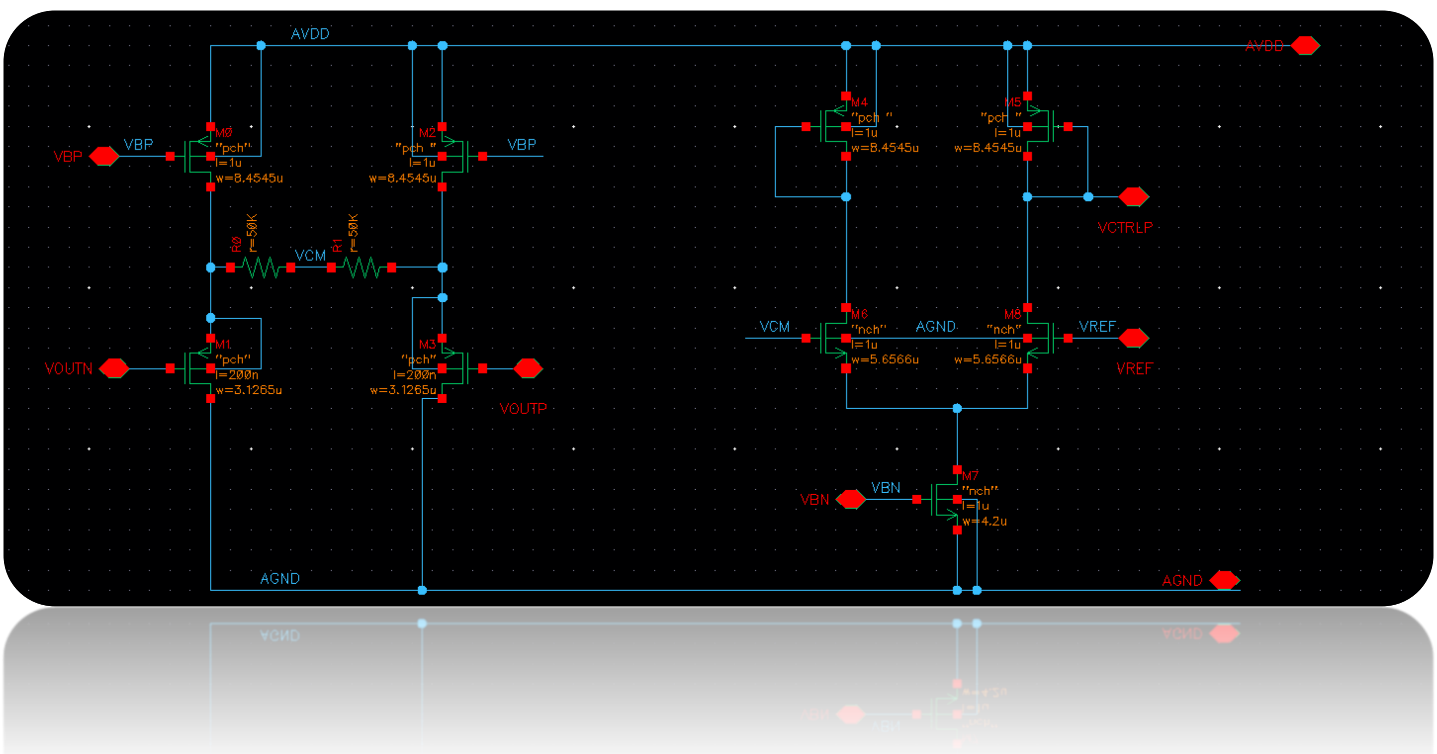
$$Css6 = 81.18fF, Cdd11 = 14.1fF, cdd15 = 11.64fF$$

Parameter	Hand analysis	Simulation
Gain	3.325k	3.214k
Gain(db)	70.436	70.14
Bandwidth	16.77k	15.54k
GBW	55.76M	50.06M
UGF	55.76M	49.89M
PM	81.87	89

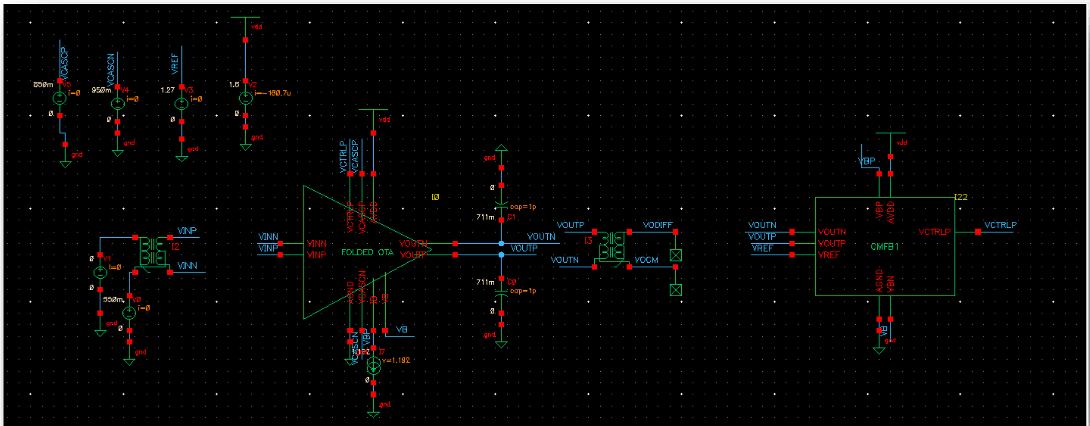
PART 4: Open-Loop OTA Simulation (Actual CMFB)

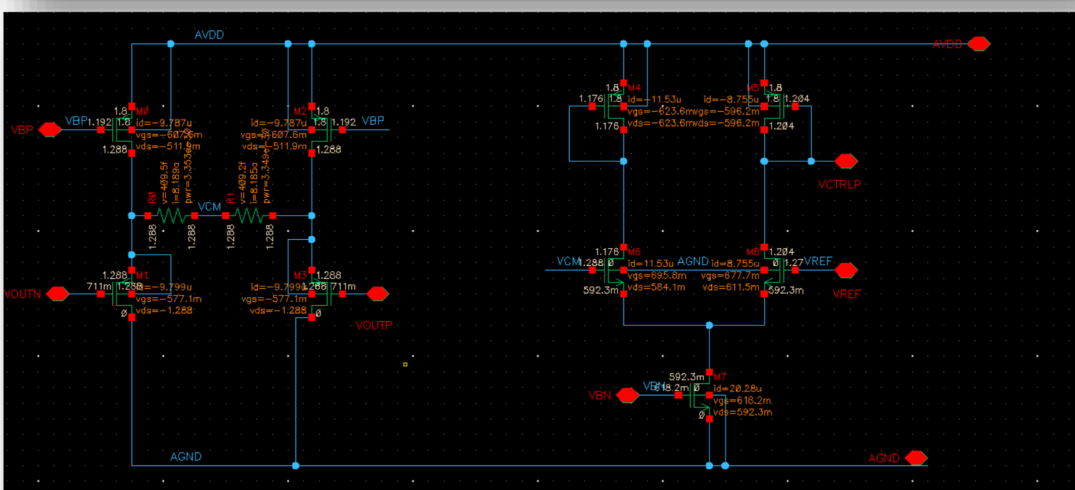
Parameter	Gm/id	Id	W	L	VGS	V*
M0&M2&M5&M4	10	10u	8.45u	1u	608.67m	200.97m
M1&M3	15	10u	3.126u	1u	597.36m	134.3m
M6&M8	15	10u	5.656u	1u	535.09m	134.06m
M7	10	20u	4.2u	1u	614.04m	200.83m

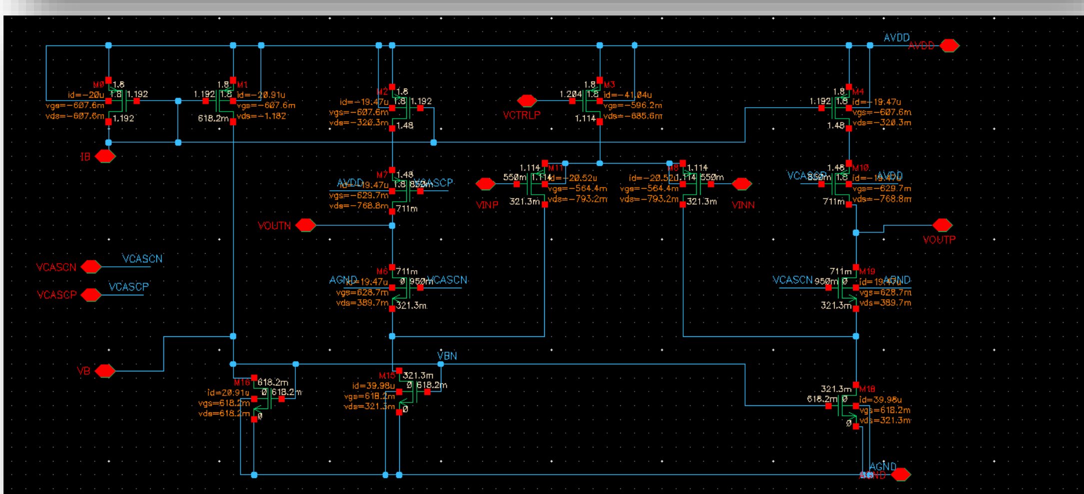
- **VOUTmax= VDD – V* – |VGSP|=1.8-200.97m-597.36m=1.0175V**
- **VOUTmin= v*+v*=134.35m+200.76m=0.3351V**
- **VREF=middle value+ |VGSP|=1.27V**

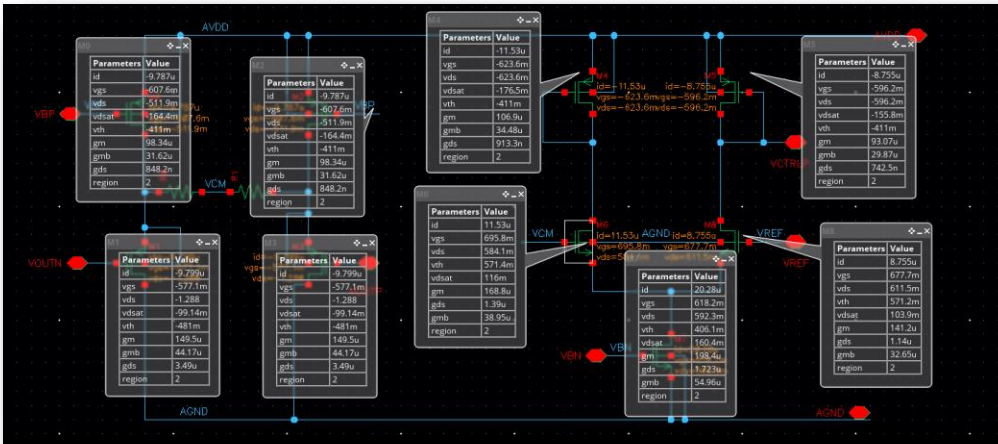


1) Schematic of the OTA and CMFB circuit with DC node voltages and transistors OP parameters (id, vgs, vds, vdsat, vth, gm, gds, region) clearly annotate









- **VOCM=711m**
-

	v("/I22/VCM" ?result "dcOp")-v("/V
V	v("/I22/...Op") (V)
1 1.270	18.10E-3

Output

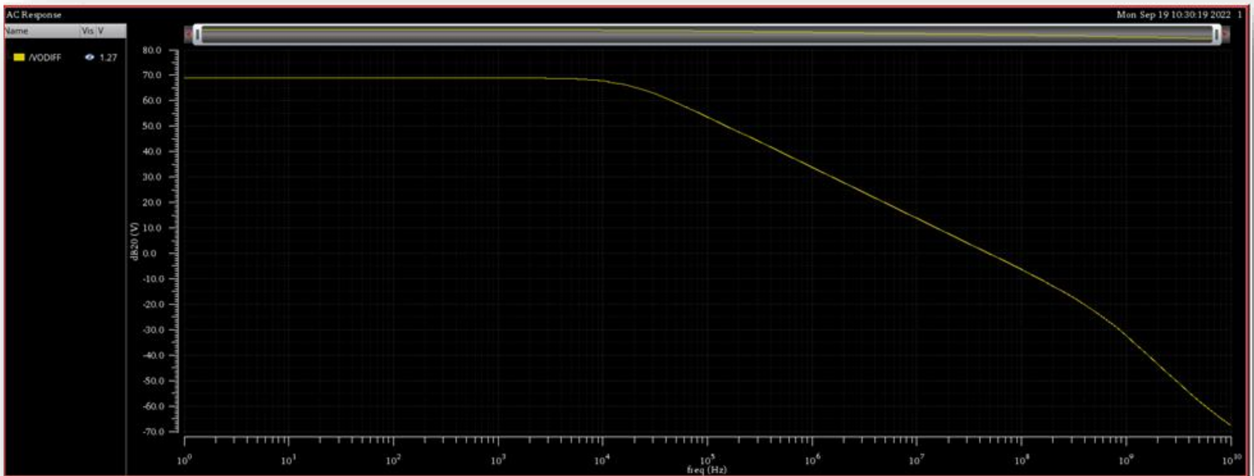
	v("/VCTRLP" ?result "dcOp")-v("/V
V	v("/VCT...p") (V)
1 1.270	11.47E-3

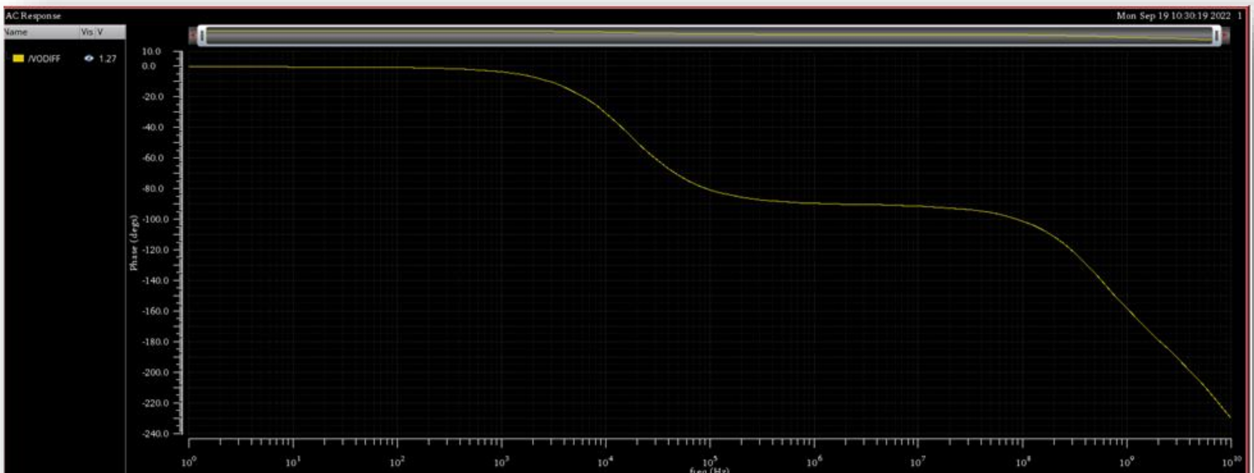
Ratio= 633m

	(v("/VCTRLP" ?result "dcOp")-v("/V
V	(v("/VC...dcOp"))
1 1.270	633.7E-3

- **the CM level at the output=0.71V, we force Vcm to equal VREF-VGSP=0.7**
- **the relation between them= CM gain of 5t-OTA which equal to** $\frac{1}{2(gm5+gmb5)RSS} = \frac{1}{2(93.07u+29.87u)*(\frac{1}{1.723u})} = 7m$

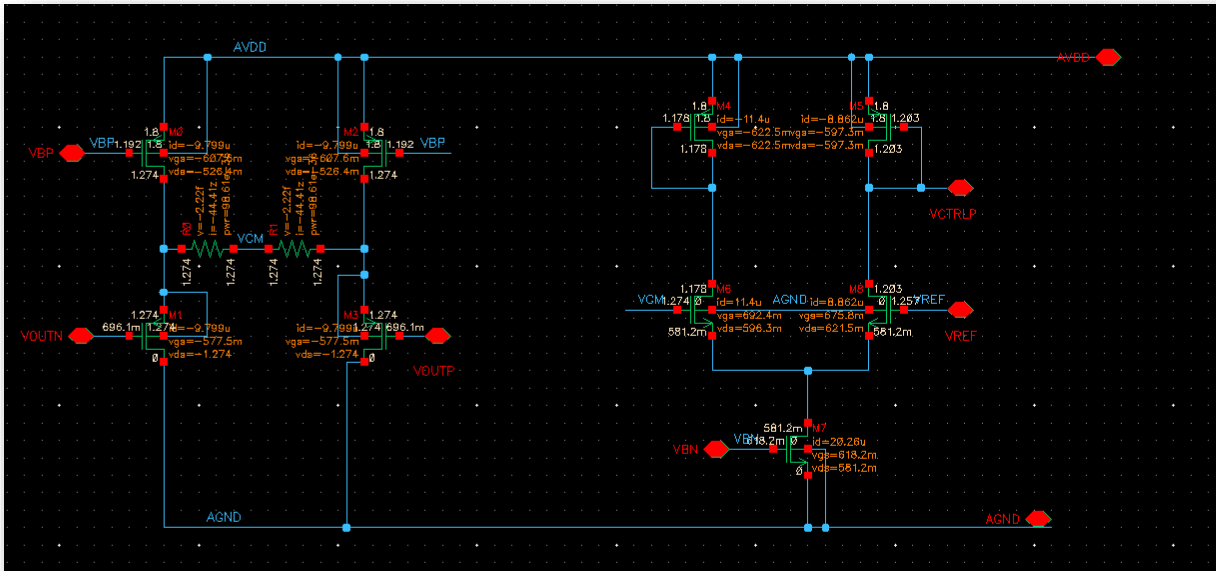
2) Diff small signal ccs:

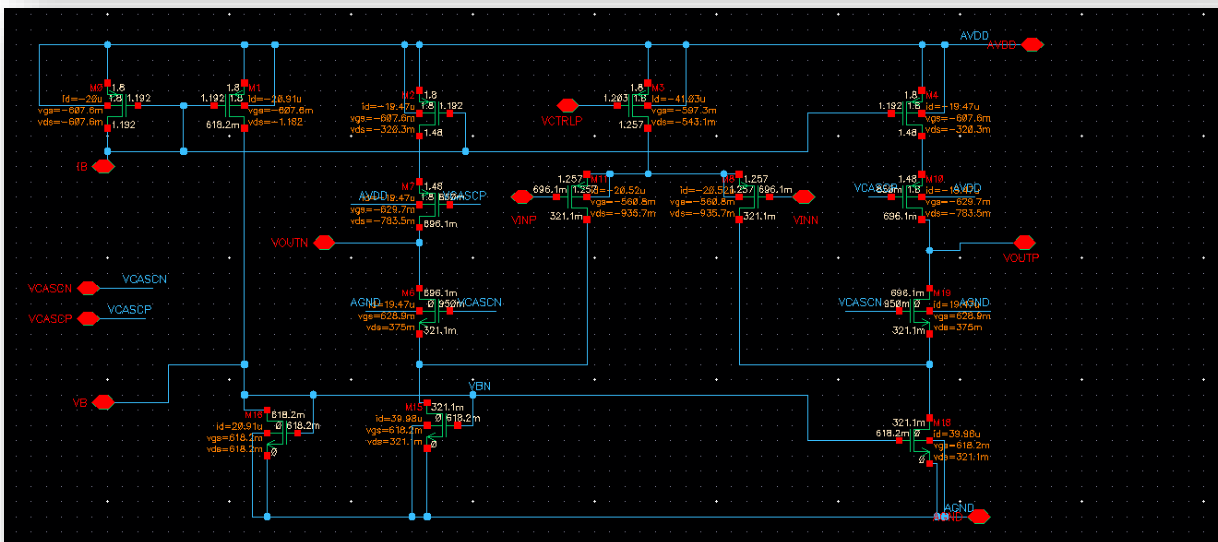




Test	Output	Nominal
lab11:TB:1	/VODIFF	
lab11:TB:1	ymax(mag(VF("/VODIFF")))	2.903k
lab11:TB:1	dB20(ymax(mag(VF("/VODIFF...	69.26
lab11:TB:1	bandwidth(VF("/VODIFF") 3 "l...	17.21k
lab11:TB:1	gainBwProd(VF("/VODIFF"))	50.07M
lab11:TB:1	unityGainFreq(VF("/VODIFF"))	49.8M
lab11:TB:1	phaseMargin(VF("/VODIFF"))	84.63

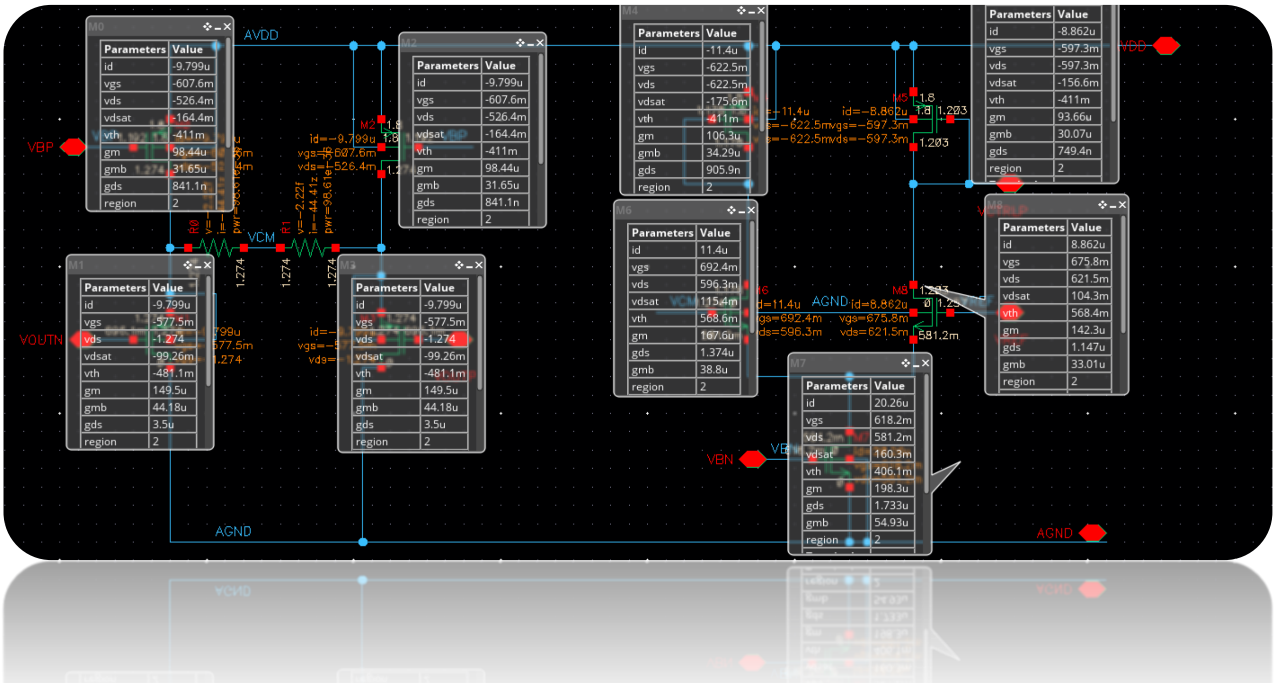
- **PART 5: Closed Loop Simulation (AC and STB Analysis)**

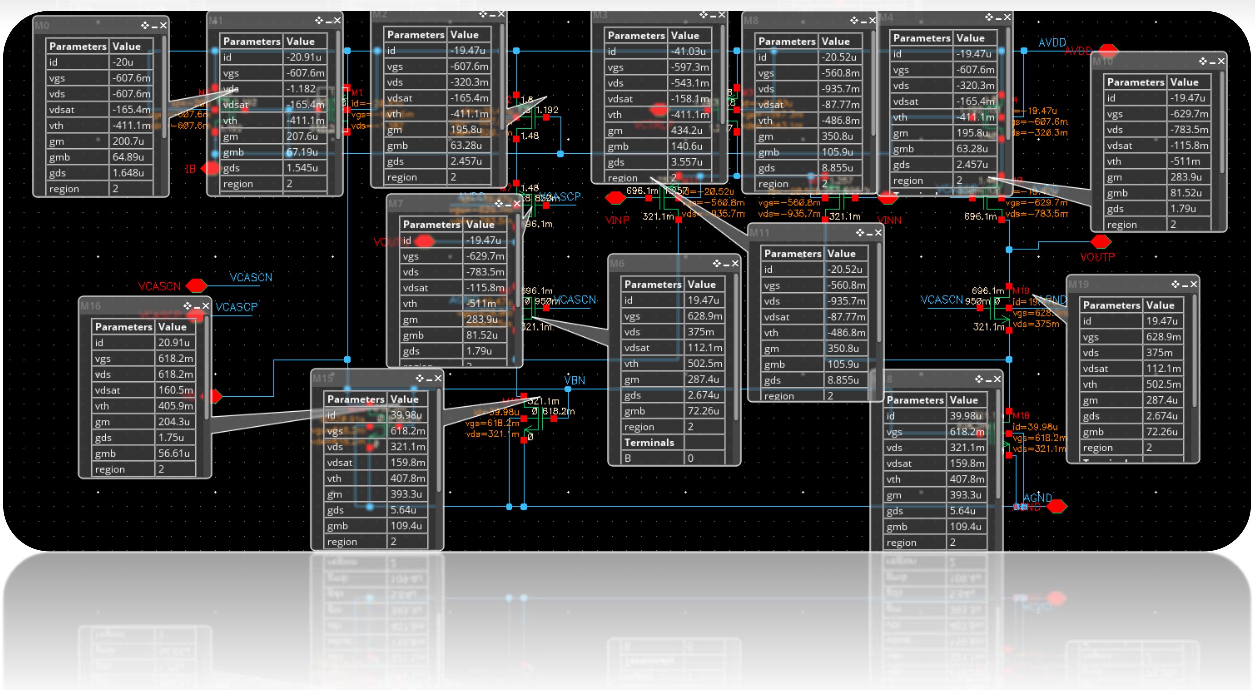




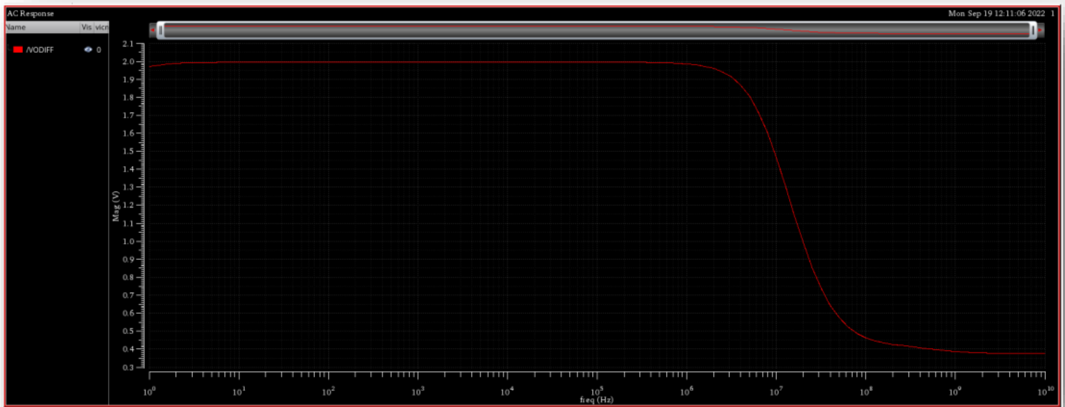
- **CM level at the OTA output = 696.1mV , as we adjusted vref at this level thus Vocm should be equal to Vref to minimize the input error.**
- **CM level at the OTA input = 696.1mV, we put vicm= 0.55 V but since we are using high resistance in the feedback 1T the input node follow the output voltage .**

- ## Dc op

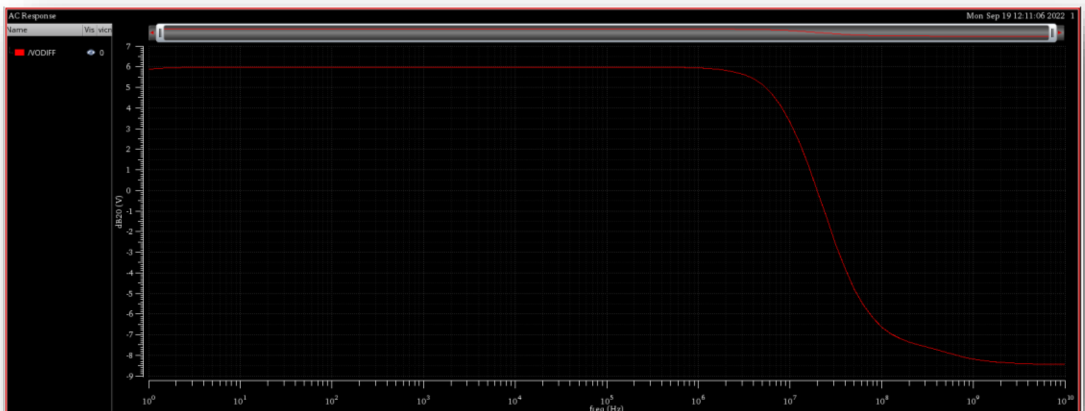

AVDD
VBP
VCM
VOUTN
AGND
VBN


AVDD
VCASCN
VCASCP
VINP
VINN
VOUTP
VBN
AGND

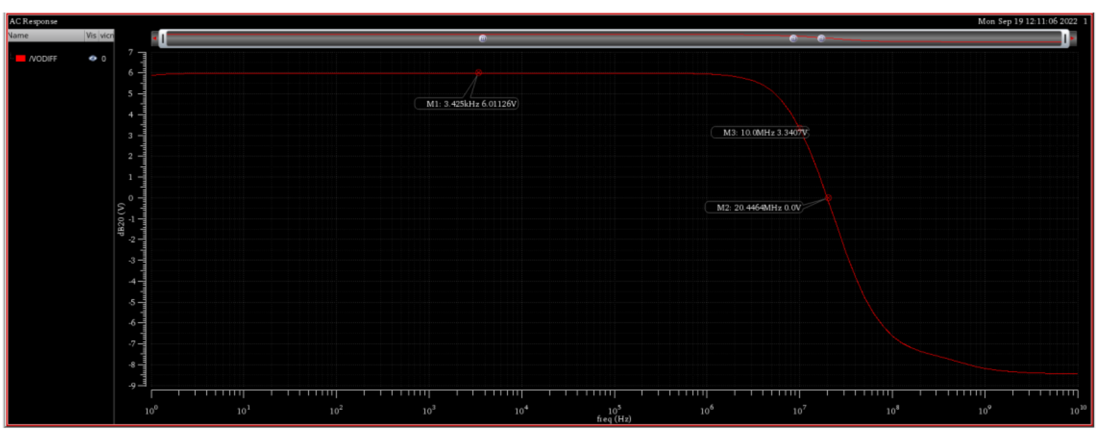
2) Differential closed-loop response:



- **Gain(db)**

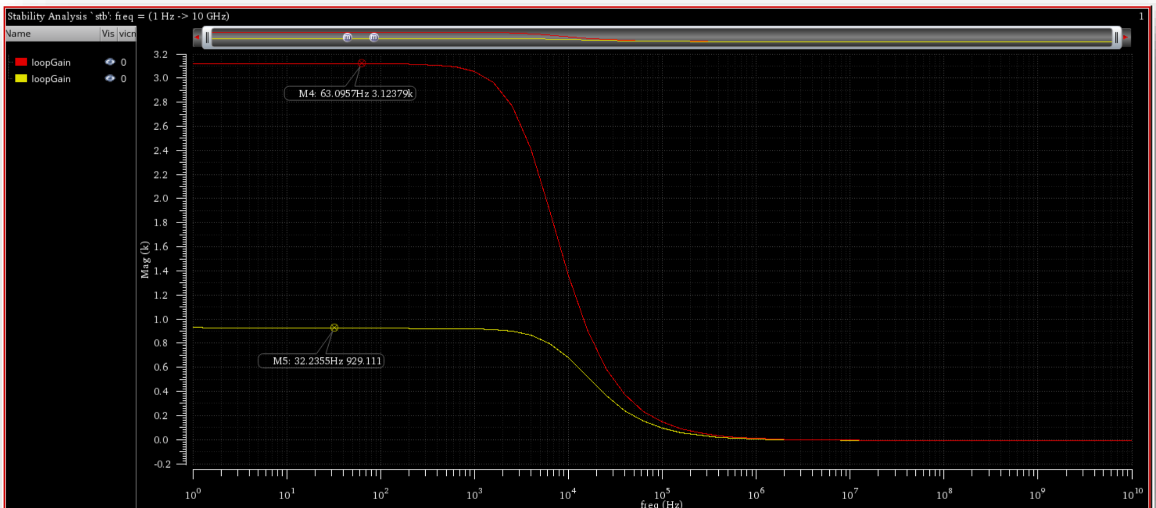


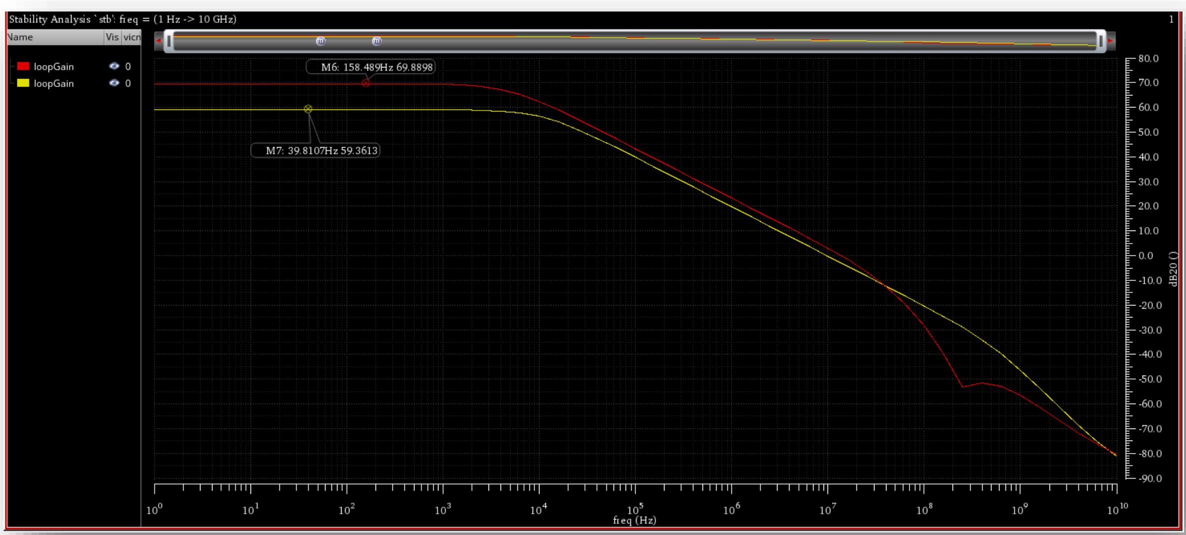
- **Use Measures or cursors to calculate circuit parameters (DC gain, CL BW, CL GBW)**

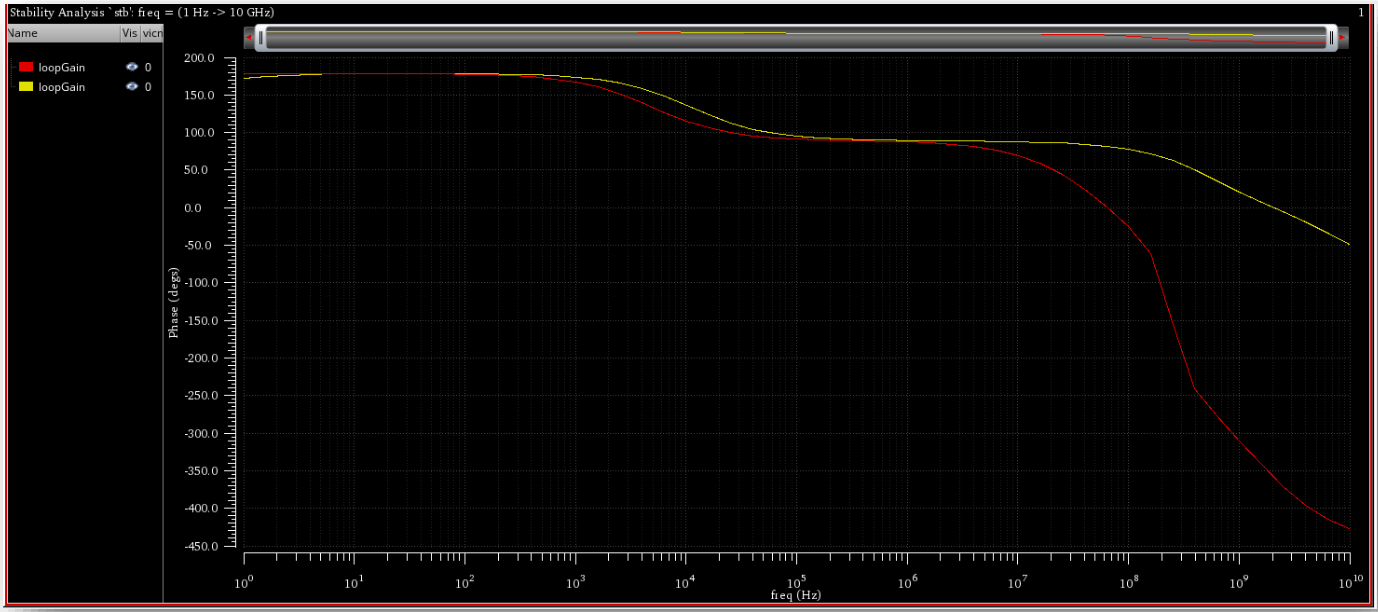


Test	Output	Nominal
lab11:part5:1	/VODIFF	
lab11:part5:1	ymax(mag(VF("/VODIFF")))	1.998
lab11:part5:1	dB20(ymax(mag(VF("/VODIFF...	6.011
lab11:part5:1	bandwidth(VF("/VODIFF") 3 "l...	11.2M
lab11:part5:1	gainBwProd(VF("/VODIFF"))	22.15M
lab11:part5:1	unityGainFreq(VF("/VODIFF"))	19.85M

3) Differential and CMFB loops stability (STB analysis):







• Phase margin

/phaseMargin	
vicm	/phase... (Deg)
1 0.000	63.39

gainBwProd(value(mag(getData(	
Expression	Value
1 gainBwProd(v...	10.15E6

/phaseMargin	
vicm	/phase... (Deg)
1 0.000	88.96

gainBwProd(value(mag(getData(	
Expression	Value
1 gainBwProd(v...	15.40E6

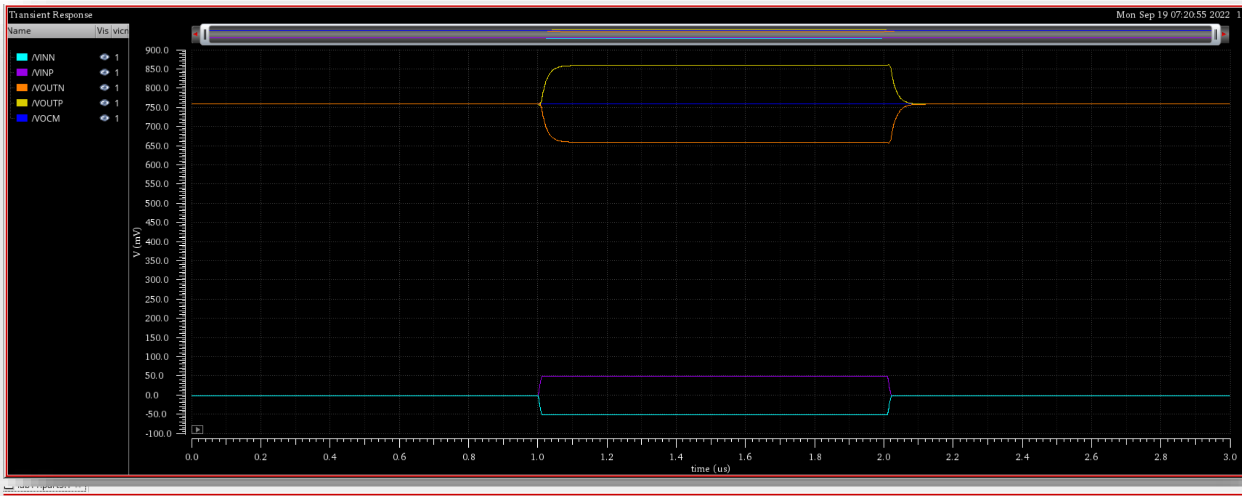
- **GBW diff < GBW CM , PM diff> PM CM**
- **Compare DC LG and GBW of the diff loop with those obtained from open-loop simulation. Comment**

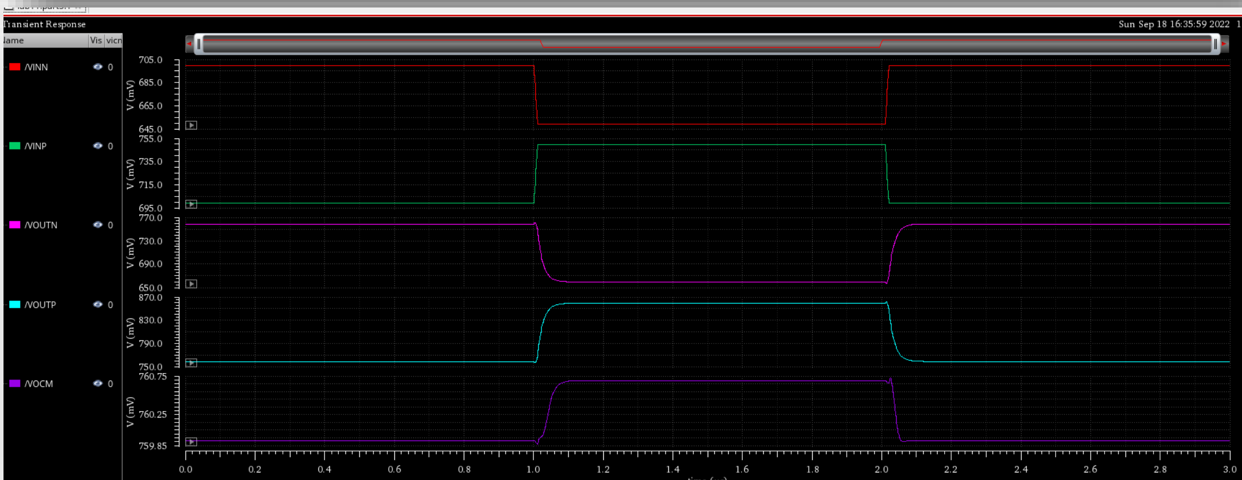
Parameter	Diff LG	Diff Open loop
DC gain	59.36 db	69.26 db
GBW	10.15M	50.07M

- **As β=1/3 → Diff LG=1/3*AOL=59.36db**
- **GBW=gain*BW ,as gain decreases by factor 1/3 so GBW decreases by 1/3**

PART 6: Closed Loop Simulation (Transient Analysis)

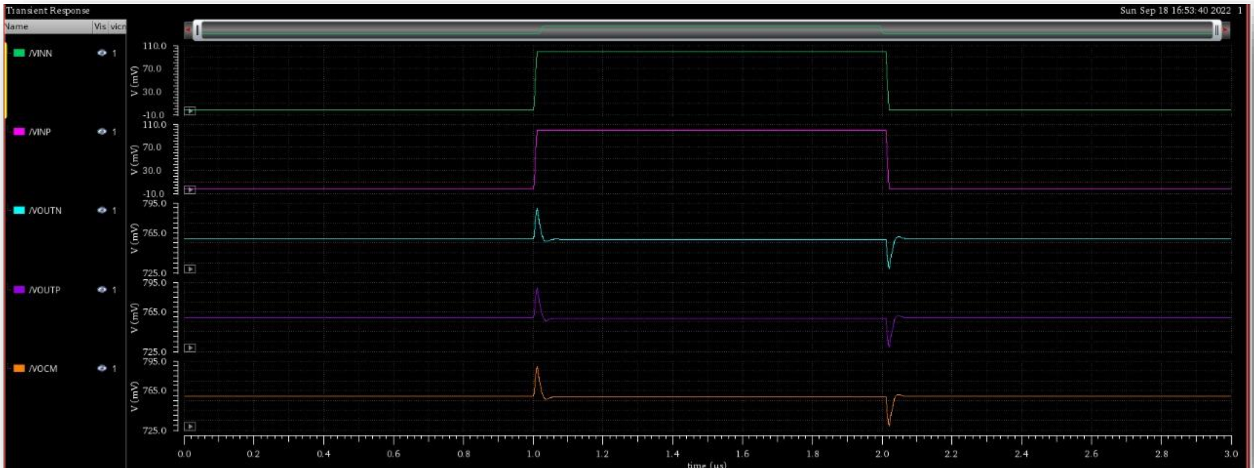
1) Differential and CMFB loops stability (transient analysis):





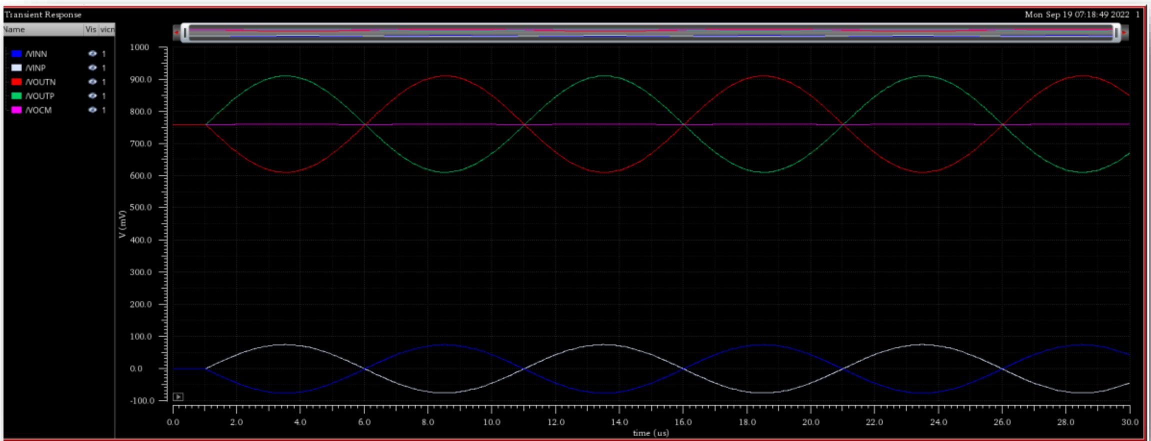
- **No, ringing in time domain , yes both are stable**

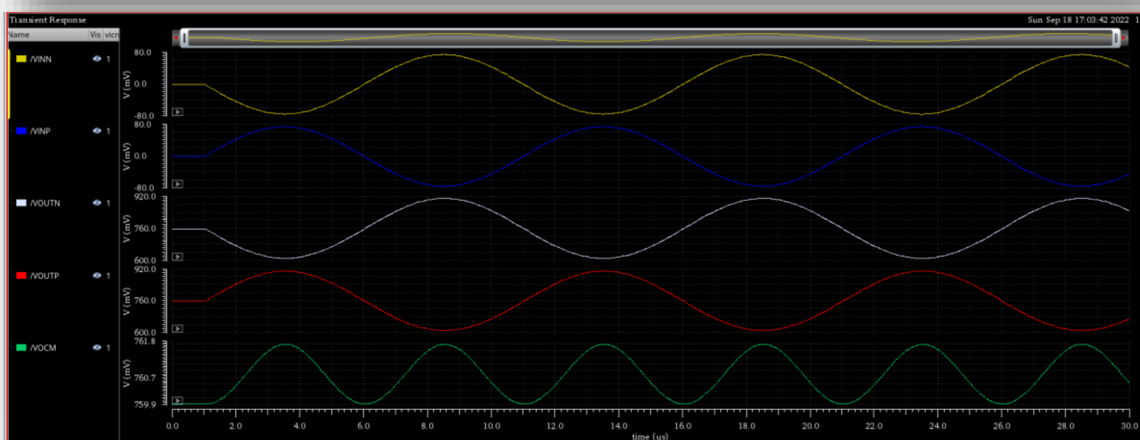
- **Set differential input to zero and apply the same previous pulse at the balun CM input**



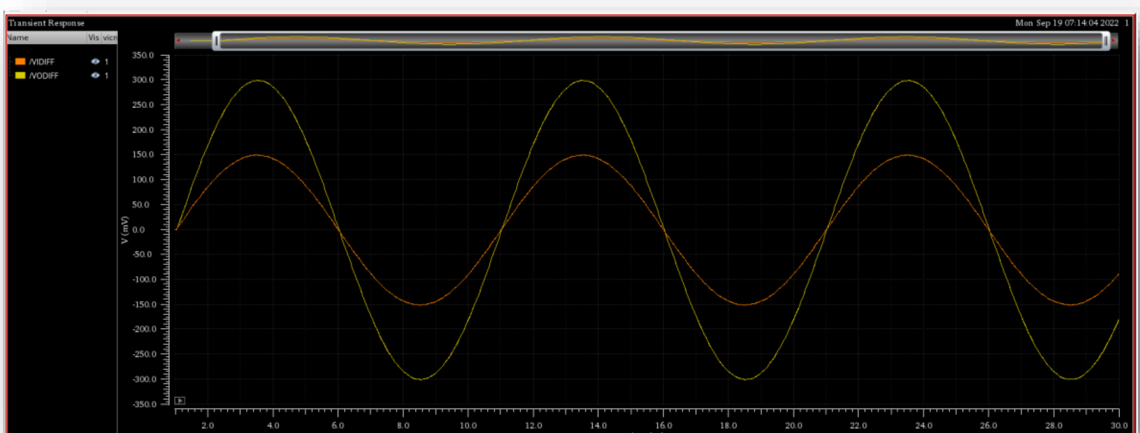
- **Yes there are CM ringing in time domain , since CM PM in stp analysis = 63.3 which is smaller than 67 so the CM is underdamped.**

2) output swing





- **Voutdiff vs vindiff**



peakToPeak(value(getData("/VO

	Expression	Value
1	peakToPeak(v...	599.3E-3

peakToPeak(value(getData("/VID

	Expression	Value
1	peakToPeak(v...	300.0E-3