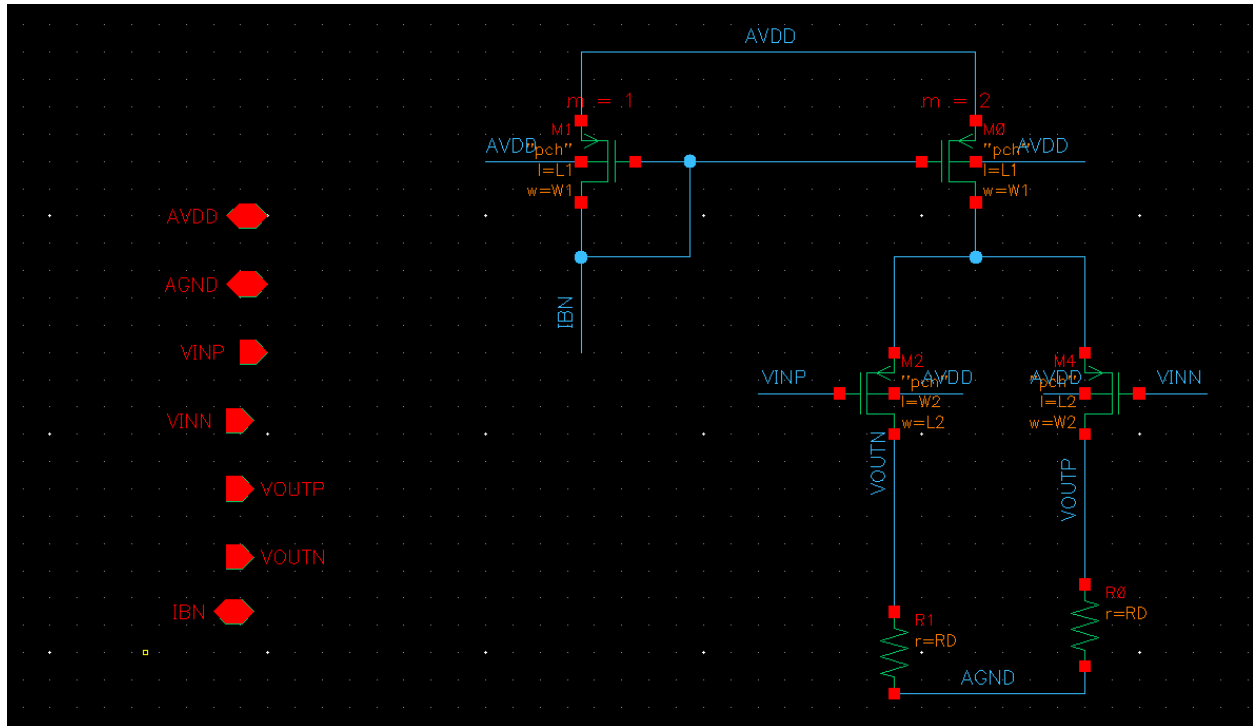


PART 1: Differential Amplifier Design

1 CIRCUIT



2 CHOOSE ***RD*** TO MEET THE CM OUTPUT LEVEL SPEC.

$$RD = \frac{0.6}{20u} = 30k$$

3 CHOOSE ***V**** TO MEET THE DIFFERENTIAL GAIN SPEC.

$$V^* = \frac{1.82VRD}{|Av|} = 136.5mv$$

- 4 ASSUME WE WILL SET V_{DS} OF THE TAIL CURRENT SOURCE TO $300mV$ TO ALLOW MORE OUTPUT SWING. REPORT THE INPUT PAIR SIZING USING SA.

ADT Sizing Assistant

Settings Help

LUT Settings

LUTs Directory:

LUT:

Corner:

Temp (°C):

State1 Save State

ID:

Vstar:

ro:

VDS:

VSB:

Stack:

Get Apply

Y-Expr:

Plot Replace Append

Device Parameters

#	Parameter	Value
1	ID	20u
2	L	420n
3	W	15.88u
4	VGS	643.3m
5	VDS	900m
6	VSB	300m
7	gm/ID	14.42
8	Vstar	138.7m
9	fT	797.4M
10	gm/gds	86.81
11	VA	6.021
12	ID/W	1.259
13	gm/W	18.16

ADT Sizing Assistant

Settings Help

LUT Settings

LUTs Directory:

LUT:

Corner:

Temp (°C):

State1 Save State

ID:

Vstar:

ro:

VDS:

VSB:

Stack:

Get Apply

Y-Expr:

Plot Replace Append

Device Parameters

#	Parameter	Value
13	gm/W	18.16
14	AREA	6.67p
15	gm	288.4u
16	gmb	78.47u
17	gds	3.322u
18	ro	301k
19	VTH	527.4m
20	VDSAT	111.7m
21	cgg	57.56f
22	cgs	45.3f
23	cgd	10.05f
24	cgb	2.218f
25	cdb	15.39f
26	csb	27.34f
27	idath2	4.097e-24

$L=420n$ & $W=15.88u$ & $V_{TH}=527.4mV$ & $|V_{GS}|=643.3mV$

- 5 GIVE THE ABOVE ASSUMPTION, CALCULATE THE CM INPUT LEVEL.
CALCULATE THE MIN AND MAX CM INPUT LEVELS. IS THE SELECTED CM INPUT LEVEL IN THE VALID RANGE?
-

Min : $V_{ICMmin} = I_{RD} - V_{TH} = 0.6 - 0.5274 = 72.6 \text{ mV}$

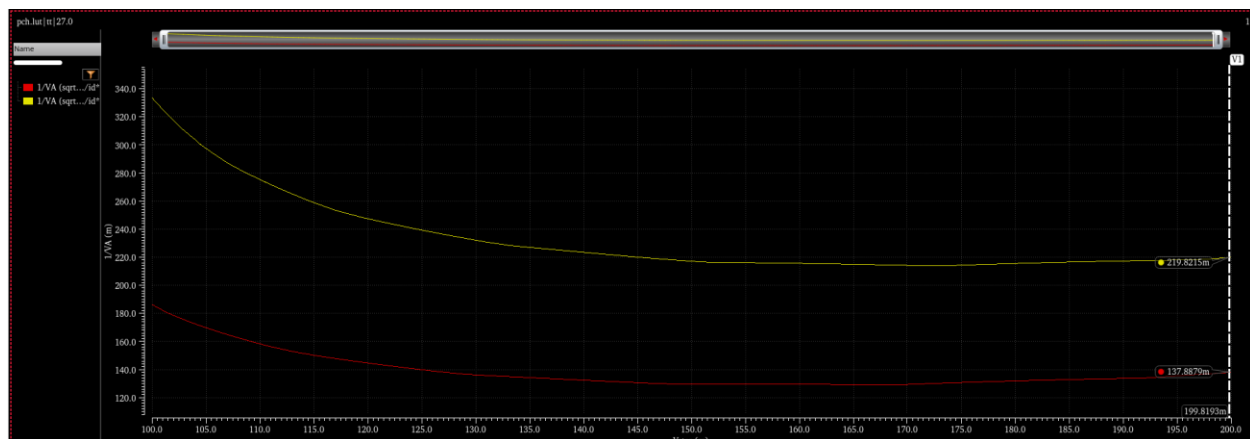
Max: $V_{iCMmax} = -V_{SG} + V_{DS} + V_{DD} = -643.3 \text{ m} - 138.7 \text{ m} + 1.8 = 1.018 \text{ V}$

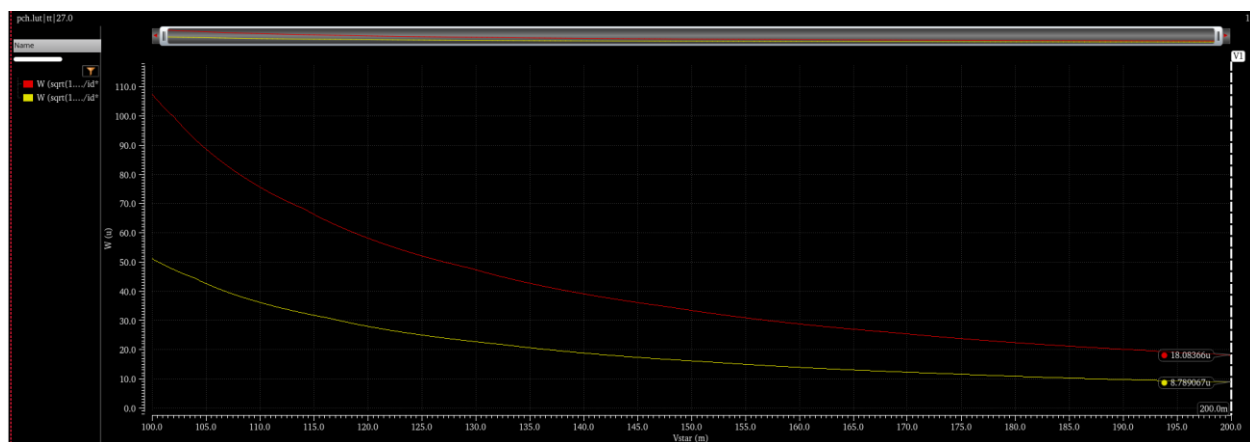
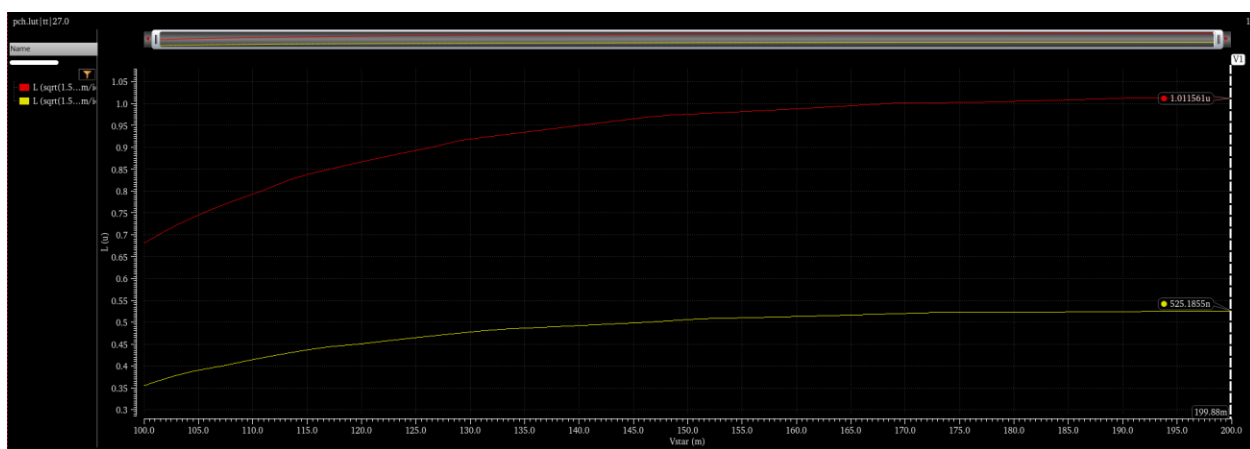
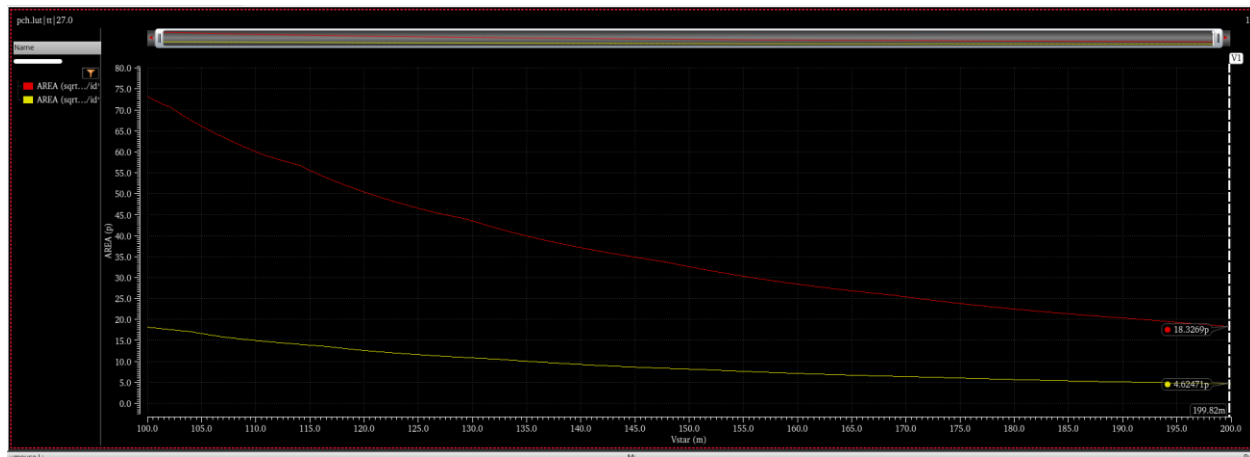
the CM input level: $V_{ICM} = -643.3 \text{ m} - 300 \text{ m} + 1.8 = 856.7 \text{ mV}$

yes, the selected CM input level in the valid range

6 SIZING THE TAIL CURRENT SOURCE

ID	20u
Vstar	100m : 200m
$\text{sqrt}(1.5) * 3.5 \text{m} / \text{sqrt}(W * L * 1 \text{e} 12) * g_m / I_D * 100$	1, 2
VDS	0.3
VSB	0





$L=525.18n$

$W=8.8u$

At $V^* = 200\text{mv}$ (the minimum mismatch is achieved at the max V^*)

1 SCHEMATIC

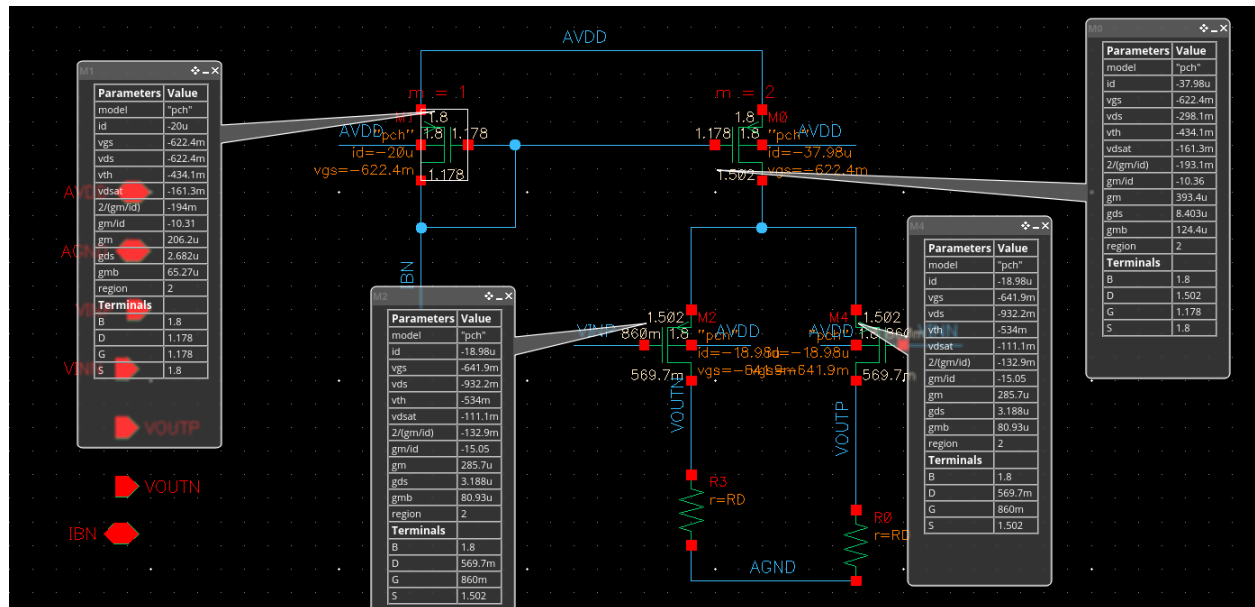


Design Variables

L1	525.17n
L2	420n
RD	30k
Vicm	0.86
Vid	0
W1	8.8u
W2	15.88u

[Click to add variable](#)

1 REPORT THE SCHEMATIC OF THE DIFF PAIR WITH DC OP POINT CLEARLY ANNOTATED.

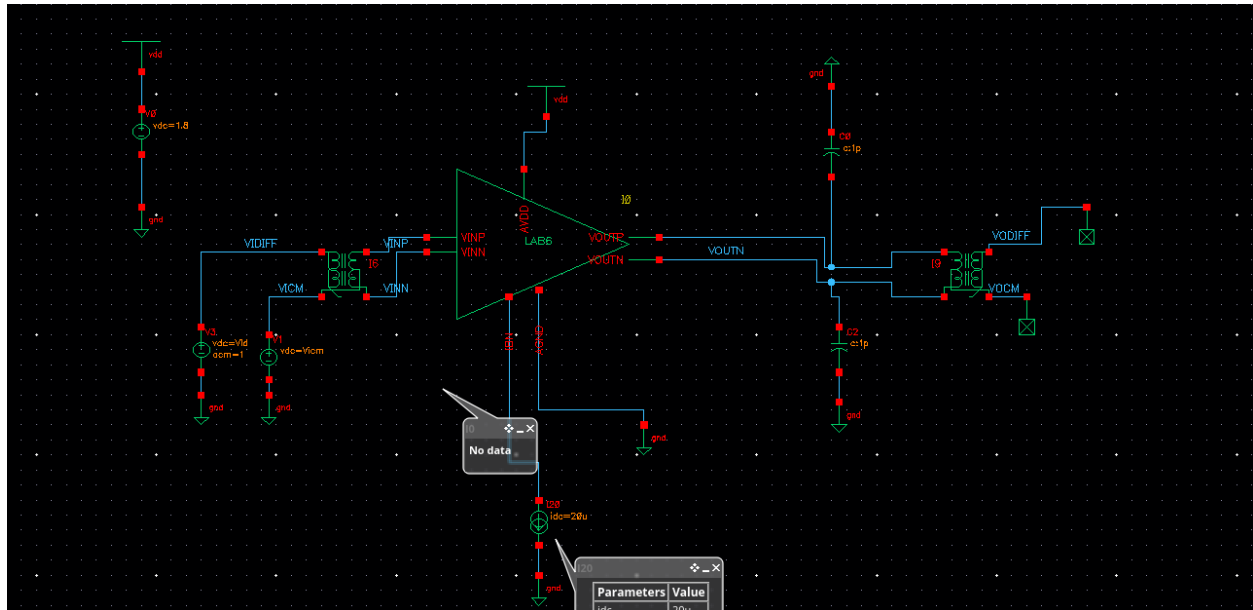


1.1 CHECK THAT ALL TRANSISTORS OPERATE IN SATURATION.

YES, they are all in region(2) saturation.

2 DIFF SMALL SIGNAL CCS:

2.1 Use AC MAGNITUDE = 1 FOR THE DIFF SOURCE (AND AC MAGNITUDE = 0 FOR THE CM SOURCE).



2.2 RUN AC ANALYSIS (1Hz:10GHz, LOGARITHMIC, 10 POINTS/DECADE).

Choosing Analyses -- ADE Assembler ✕

Analysis

<input type="radio"/> tran	<input type="radio"/> dc	<input checked="" 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 type="radio"/> lf	<input 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"/> hbstb	<input type="radio"/> hbnoise
<input type="radio"/> hbsp	<input type="radio"/> hbxf		

AC Analysis

Sweep Variable

☒ 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 ☐

Add Points By File ☐

Specialized Analyses

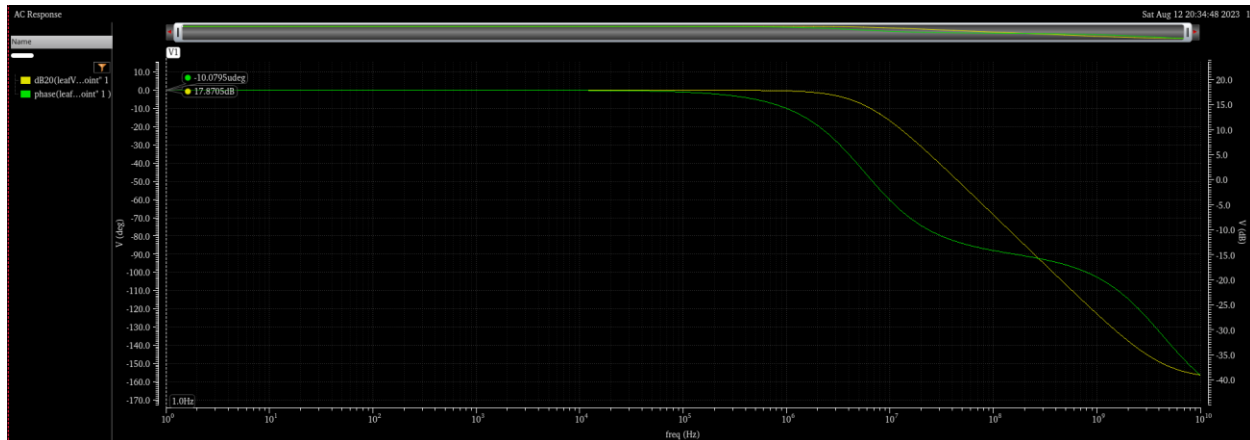
None ▼

Enabled ☒

Options...

OK Cancel Defaults Apply Help

2.3 REPORT THE BODE PLOT OF SMALL SIGNAL DIFF GAIN.



lab5_LAB6PART...	ymax(mag(VF"/...)	7.826			
lab5_LAB6PART...	bandwidth(VF"/...)	5.696M			
lab5_LAB6PART...	ymax(dB20(VF"/...	17.87			

Analytically :

$$\text{Gain} = g_{m2} (R_D // r_{o2}) = 285.8 \mu \times 27.38 \text{ k} = 7.82$$

$$\text{In db} : 20 \log(7.82) = 17.86 \text{ db}$$

$$R_{th} = (r_{o2} (g_m + g_{mb}) * r_0) // R_D = R_D$$

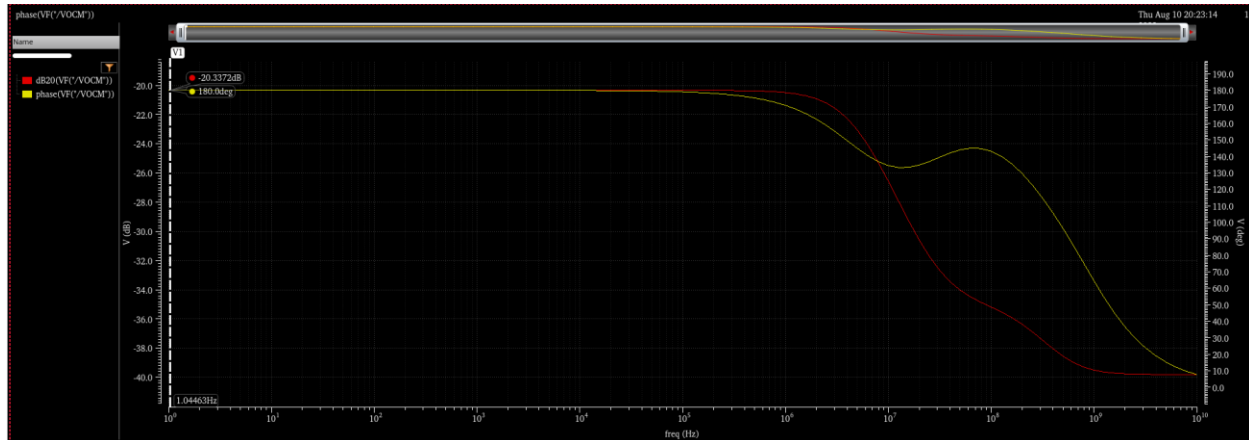
$$\omega = 1/R_{CL} = 33.4 \text{ M}$$

$$f = \omega / 2\pi = 5.3 \text{ MHz}$$

	SIM	ANALYTICAL
DC diff gain	17.87 db	17.86 db
BW	5.7 MHz	5.3 MHz

3 CM SMALL SIGNAL CCS:

3.1



3.2

lab5_LAB6PART...	ymax(dB20(VF"...	-20.34			
------------------	------------------	--------	--	--	--

3.3 COMPARE THE DC CM GAIN WITH HAND ANALYSIS IN A TABLE. IS IT SMALLER THAN "1"? WHY?

$$A_{vcm} = \frac{-gm2 * RD}{1 + 2(gm2 + gmb2) * ro0} = \frac{-285.7u * 30K}{2(285.7 + 80.93) * \frac{1}{8.403}} = 0.0982$$

$$= -20.15 \text{ DB}$$

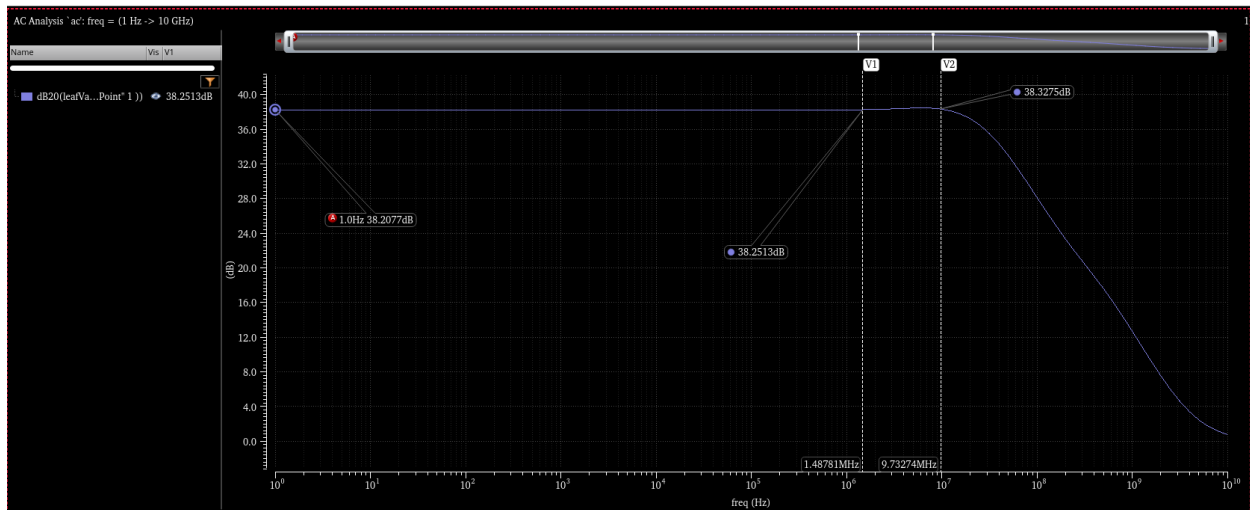
SIM	ANALYTICAL
-20.34 DB	-20.15 DB

YES, it's smaller than 1 (in decimal scale), as cm input is partially rejected and attenuated.

3.4 JUSTIFY THE VARIATION OF AVCM VS FREQUENCY.

the pole at the output causes the A_{vcm} to start dropping at high frequency as C_L is large, so it is dominant, but also there is a zero caused by the capacitances at the tail current source causes it to fall at a slower rate, as C_p degrades tail current source impedance at high frequency making bigger gain (if we neglected the changes in output impedance at high frequency).

3.5 PLOT AV_D/AV_{CM} IN DB. COMPARE AV_D/AV_{CM} @ DC WITH HAND ANALYSIS IN A TABLE.



SIM	ANALYTICAL
38.2DB	$20\log\left(\frac{7.82}{0.0982}\right)=38.02 \text{ DB}$

3.6 JUSTIFY THE VARIATION OF AV_D/AV_{CM} WITH FREQUENCY

there is a zero made a short increase, as it was a pole caused AV_{CM} to decrease, There is also a pole because of c_p degrades tail current source impedance at high frequency making Av_{cm} make more gain so the ratio itself decreases.

4 DIFF LARGE SIGNAL CCS:

4.1 USE DC SWEEP (NOT PARAMETRIC SWEEP) FOR $V_{id} = -V_{DD}:10m:V_{DD}$.

Choosing Analyses -- ADE Assembler x

Analysis

☐ tran ☒ dc ☐ ac ☐ noise

☐ xf ☐ sens ☐ dcmatch ☐ acmatch

☐ stb ☐ pz ☐ lf ☐ sp

☐ envlp ☐ pss ☐ pac ☐ pstb

☐ pnoise ☐ pxf ☐ psp ☐ qpss

☐ qpac ☐ qpnoise ☐ qpxf ☐ qpssp

☐ hb ☐ hbac ☐ hbstb ☐ hbnoise

☐ hbsp ☐ hbxf

DC Analysis

Save DC Operating Point ☒

Hysteresis Sweep ☐

Sweep Variable

☐ Temperature

☒ Design Variable Variable Name

☐ Component Parameter

☐ Model Parameter

Sweep Range

☒ Start-Stop Start Stop

☐ Center-Span

Sweep Type

☒ Step Size

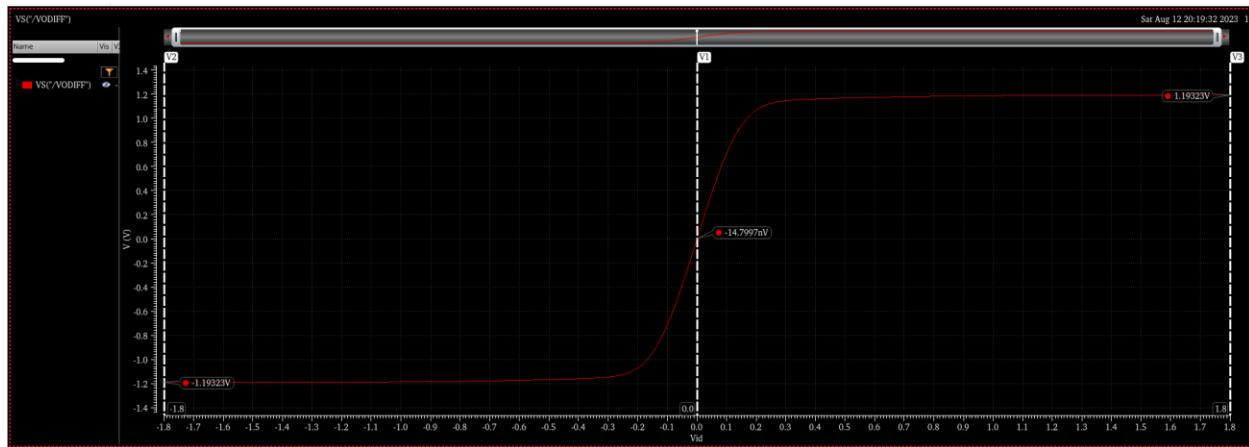
☐ Number of Steps

Add Specific Points ☐

Add Points By File ☐

Enabled ☒

4.2 REPORT DIFF LARGE SIGNAL CCS (VODIFF vs VIDIFF). COMPARE THE EXTREME VALUES WITH HAND ANALYSIS IN A TABLE.



$$VOP (@ vid=1.8v)=RD*ISS=30k*40u=1.2v$$

$$VON (@ vid=1.8v)=0$$

$$VOD(@ vid=1.8v) = 1.2v$$

$$VOP (@ vid=-1.8v)=0$$

$$VON (@ vid=-1.8v)= 30k*40u=1.2v$$

$$VOD(@ vid=-1.8v) =0-1.2v= -1.2v$$

$$VOP (@ vid=0v)= 30k*20u=0.6v$$

$$VON (@ vid=0v)= 30k*20u=0.6v$$

$$VOD(@ vid=0v) =0.6-0.6v=0v$$

	Sim	analytical
-1.8	-1.19	-1.2
0	15 n	0
1.8	1.19	1.2

5 CM LARGE SIGNAL CCS (REGION VS VICM):

5.1 USE DC SWEEP (NOT PARAMETRIC SWEEP) FOR $V_{ICM} = 0:10m:V_{DD}$ (NO NEED TO RUN AC SIM)

Choosing Analyses -- ADE Assembler x

Analysis

<input type="radio"/> tran	<input checked="" 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 type="radio"/> lf	<input 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"/> hbstb	<input type="radio"/> hbnoise
<input type="radio"/> hbasp	<input type="radio"/> hbxf		

DC Analysis

Save DC Operating Point ☒

Hysteresis Sweep ☐

Sweep Variable

☐ Temperature

☒ Design Variable Variable Name

☐ Component Parameter

☐ Model Parameter

Sweep Range

☒ Start-Stop Start Stop

☐ Center-Span

Sweep Type

☒ Step Size

☐ Number of Steps

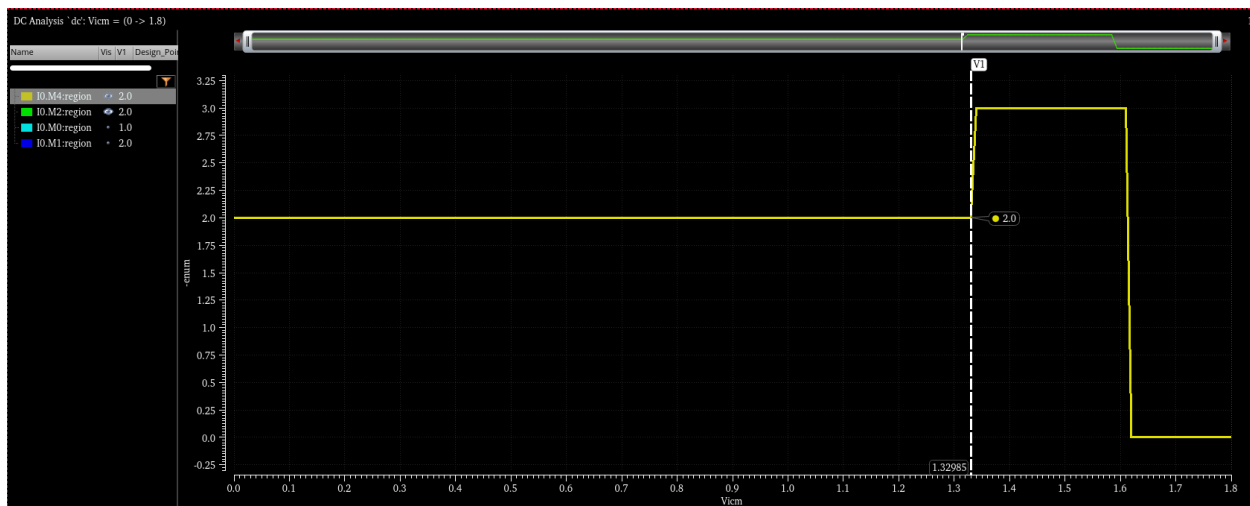
Add Specific Points ☐

Add Points By File ☐

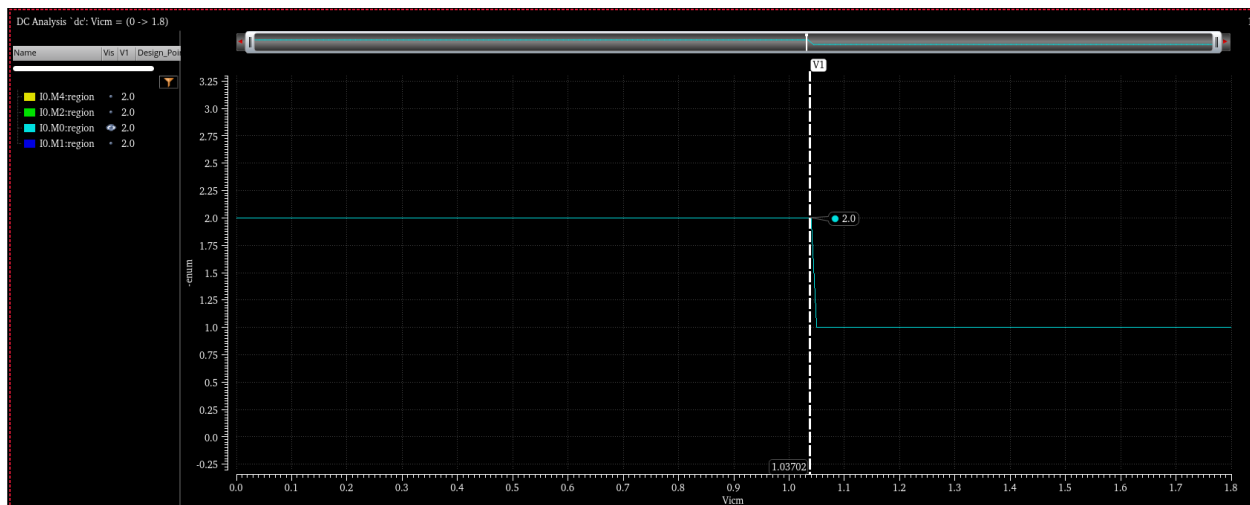
Enabled ☒

5.2 PLOT “REGION” OP PARAMETER VS VICM FOR THE INPUT PAIR AND THE TAIL CURRENT SOURCE.

INPUT PAIR:



TAIL CURRENT:



5.3 FIND THE CM INPUT RANGE (CMIR). COMPARE WITH HAND ANALYSIS IN A TABLE.

To keep the input pair and the tail current source both in saturation (region 2) the range is 0 to 1.037v from the graph.

ANALYTICALLY:

$$\text{Min : } \text{VICMmin} = \text{IRD} - \text{VTH} = 35.4\text{mV}$$

$$\text{Max: } \text{ViCMmax} = -\text{VSG2} - \text{V}^* + \text{VDD} = -641.9\text{ m} - 193.1\text{ m} + 1.8 = 965\text{m}$$

$$= 965\text{m} - 35.4\text{m} = 929.6\text{mv}$$

SIM	ANALYTICALLY
1.037	929.6mv

6 CM LARGE SIGNAL CCS (GBW vs VICM):

6.1 USE AC ANALYSIS (START = 1, STOP = 1, PTS(LINEAR) = 1) TO GET AVD. USE PARAMETRIC SWEEP (NOT DC SWEEP) FOR VICM = 0:20M:VDD.

Choosing Analyses -- ADE Assembler

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

AC Analysis

Sweep Variable: ☐ Frequency ☒ Design Variable ☐ Temperature ☐ Component Parameter ☐ Model Parameter ☐ None
At Frequency (Hz): 1
Variable Name: Vicm
Select Design Variable

Sweep Range

☒ Start-Stop ☐ Center-Span
Start: 0 Stop: 1.8

Sweep Type

Linear ☒ Step Size: 20m ☐ Number of Steps

Add Specific Points: ☐
Add Points By File: ☐

Specialized Analyses

None

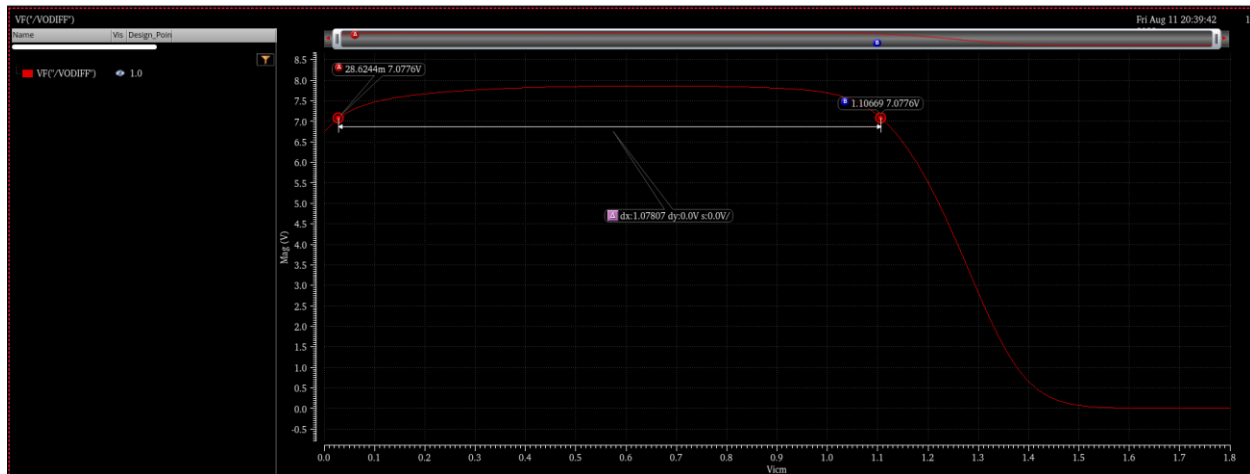
Enabled: ☒ Options...

OK Cancel Defaults Apply Help

lab5_LAB6PART...	ymax(mag(VF("VODIFF")))	7.864			
------------------	-------------------------	-------	--	--	--

$$A_{vd}(\max) = 7.864$$

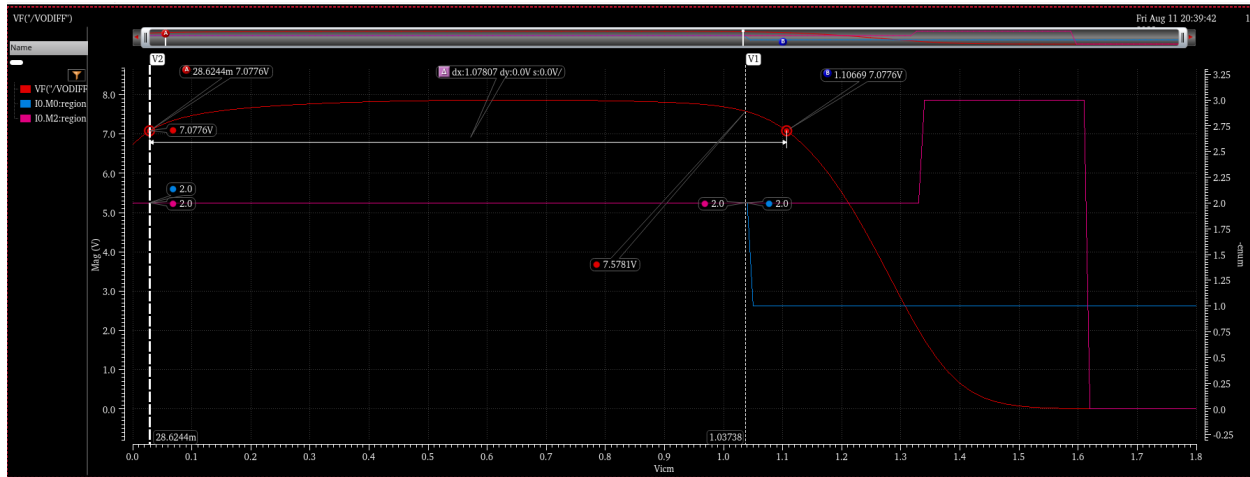
6.2 REPORT CM LARGE SIGNAL CCS (A_{VD} VS V_{ICM}). ASSUME THE VALID RANGE FOR V_{ICM} (CMIR) IS DEFINED BY THE CONDITION THAT A_{VD} IS WITHIN 90% OF THE MAX GAIN, I.E., 10% DROP IN GAIN.



$$90\% * 7.864 = 7.0776$$

The range is 1.078 v

6.3 PLOT THE RESULTS OVERLAID ON THE RESULTS OF THE PREVIOUS METHOD (REGION PARAMETER). FIND THE CM INPUT RANGE. COMPARE WITH THE PREVIOUS METHOD IN A TABLE



the cm input range is within the 10% drop and the transistors in saturation

$$Vicm = 1.037 - 28.62m = 1.008 \text{ V}$$

Above 90% gain	Region only	Both
1.078v	1.037v	1.008v