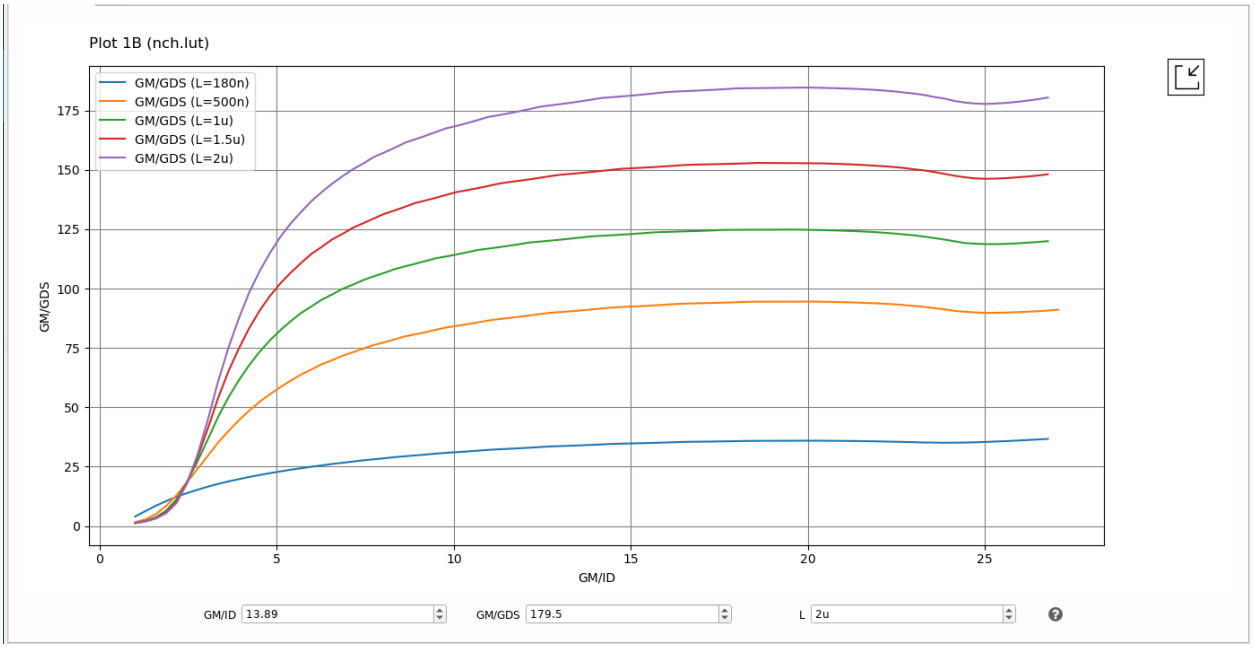
Part1

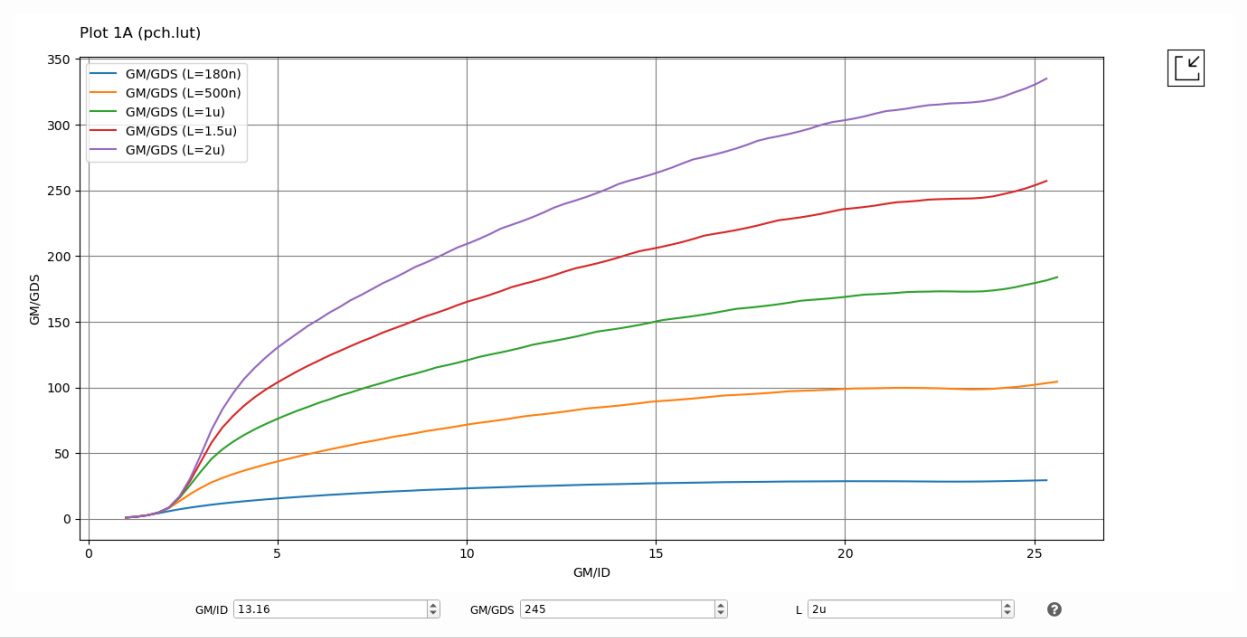
1 Using ADT Device Xplore, plot the following design charts vs gm/ID for both PMOS and NMOS. Set VDS = VDD/3 and L = 0.18u,0.5u:0.5u:2u

1.1 gm/gds

NMOS

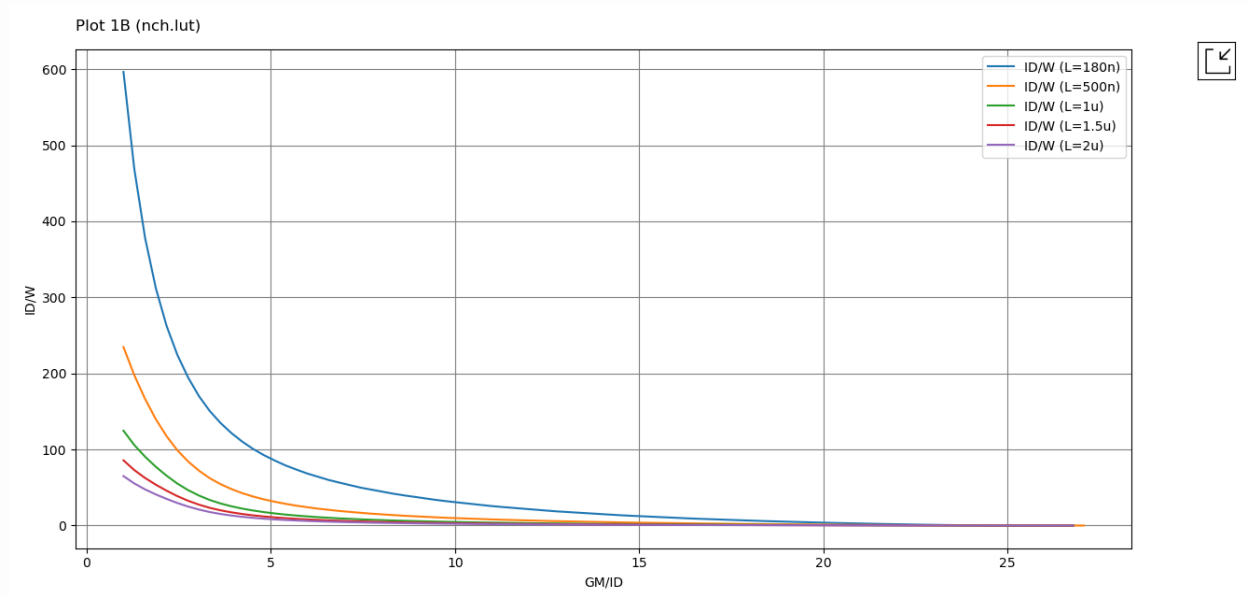


PMOS

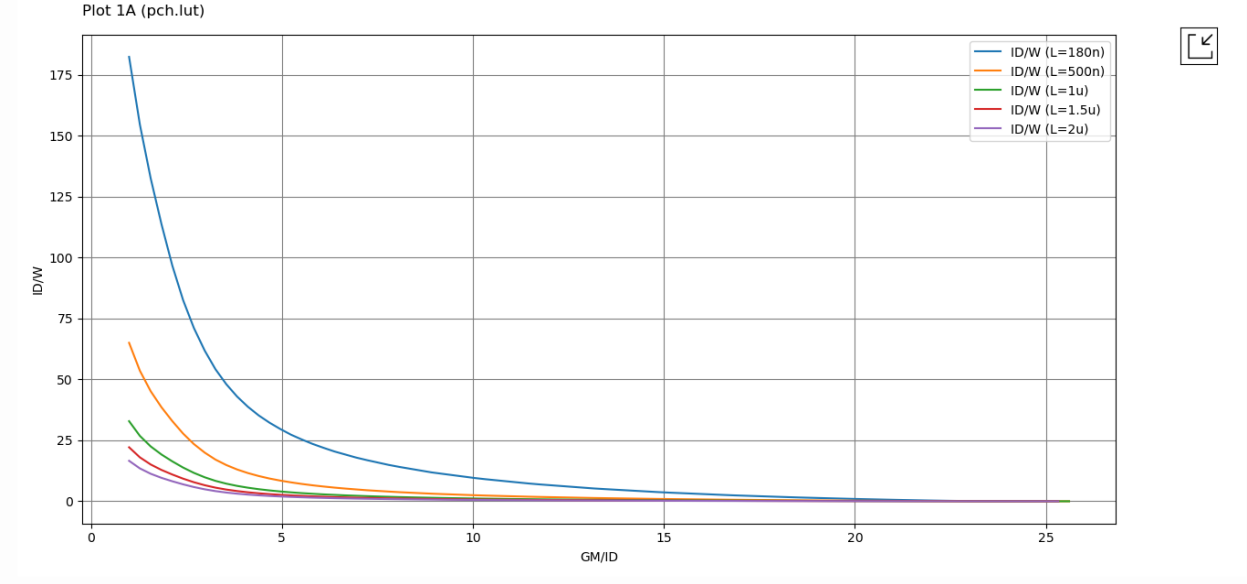


1.2 ID/W

NMOS

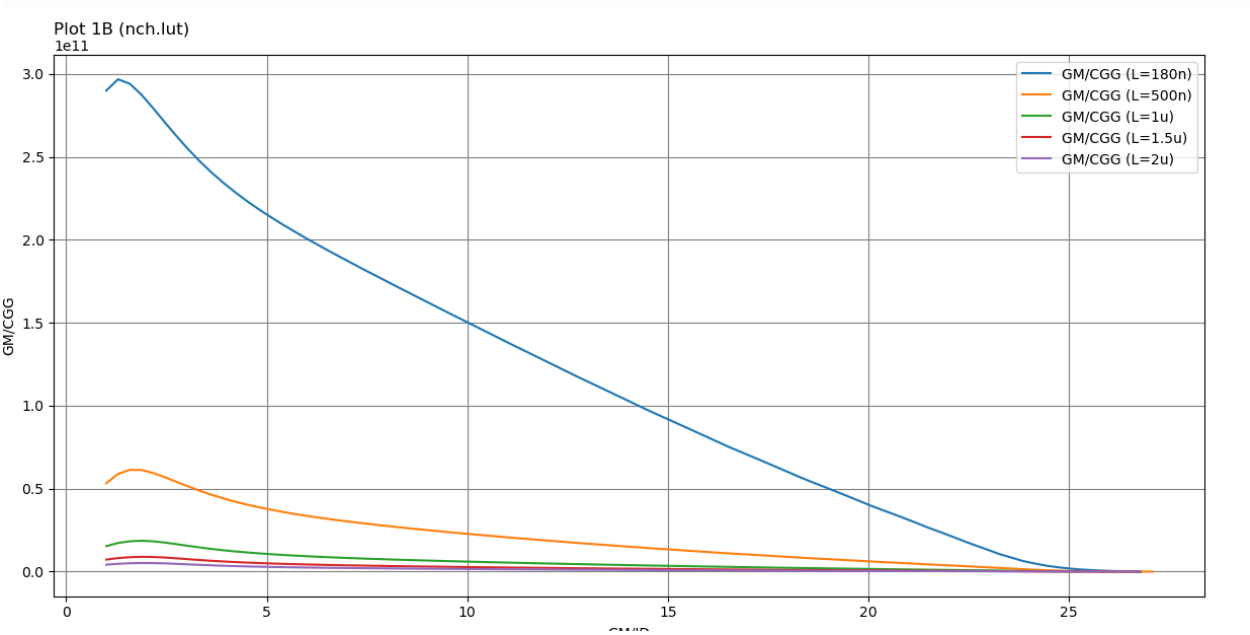


PMOS

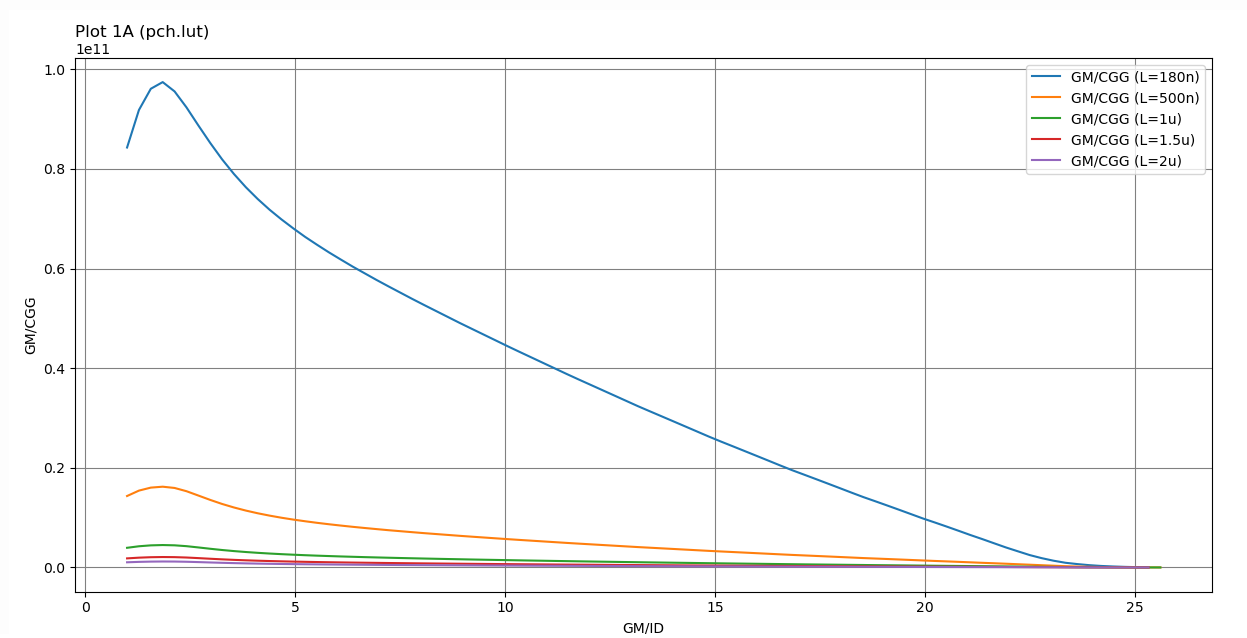


1.3 GM/CGG

NMOS

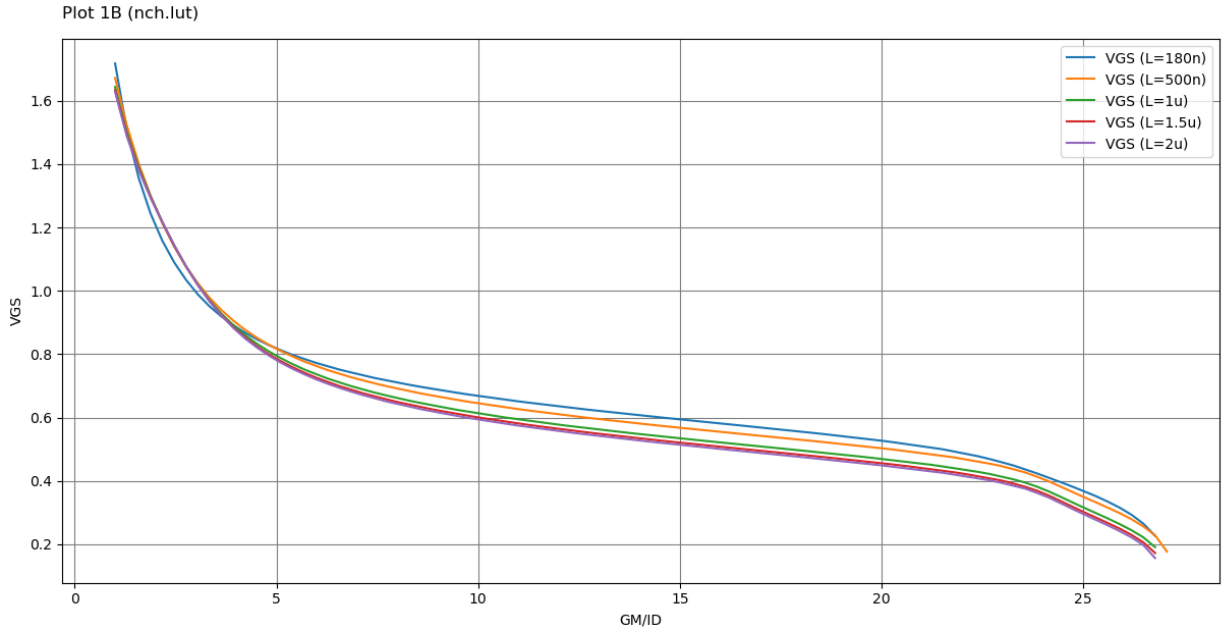


PMOS

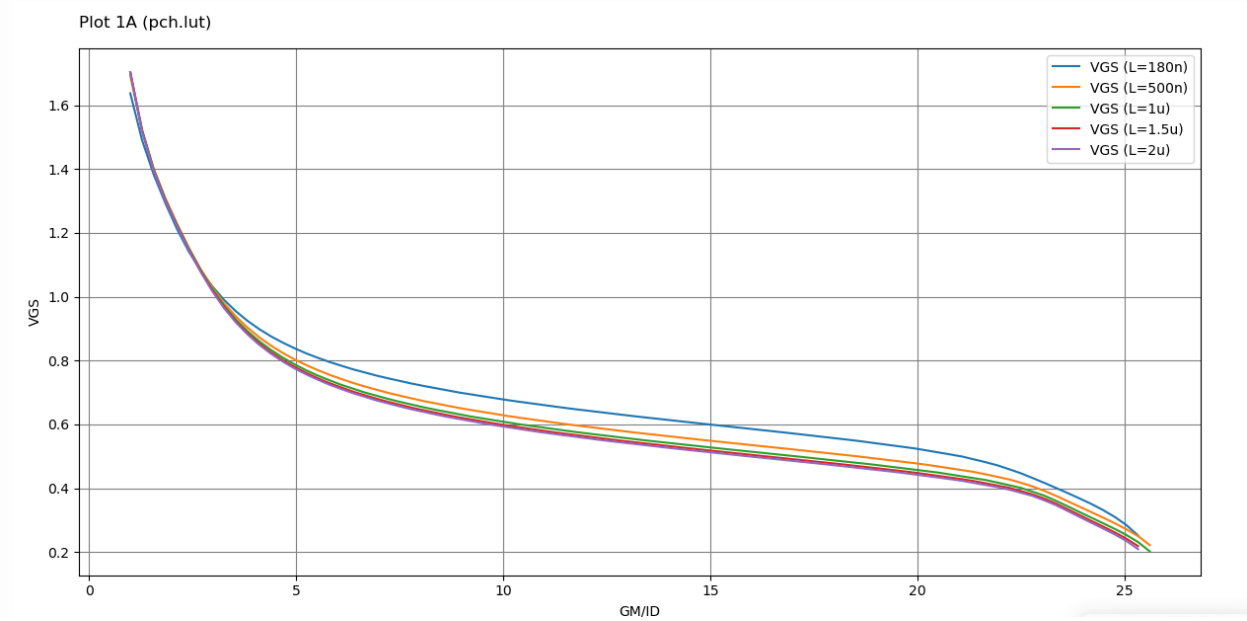


1.4 VGS

Nmos



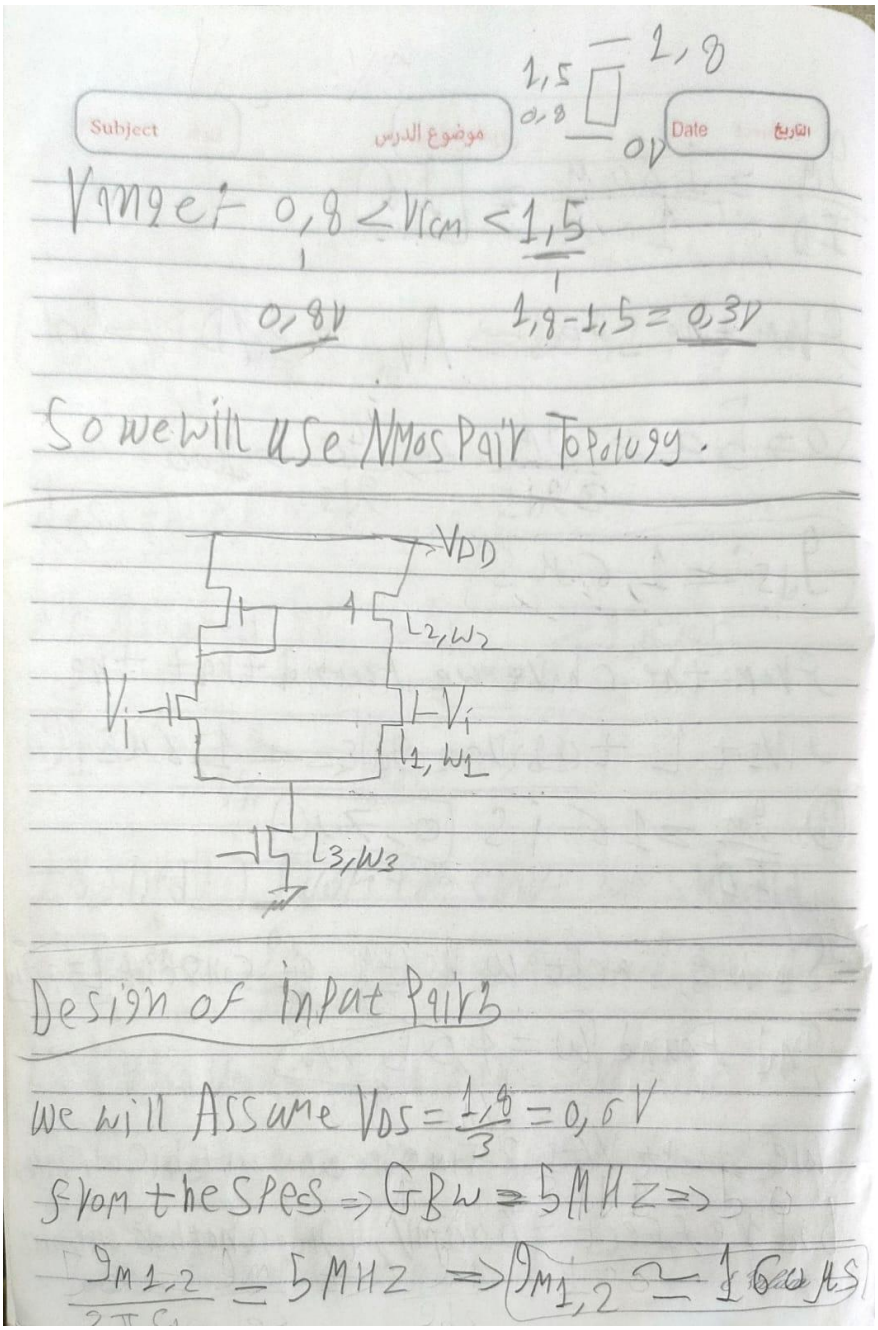
PMOS


Plot 1A (pch.lut)
VGS (L=180n)
VGS (L=500n)
VGS (L=1u)
VGS (L=1.5u)
VGS (L=2u)
VGS
GM/ID
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
5
10
15
20
25

PART2

1 DETAILED DESIGN PROCEDURE AND HAND ANALYSIS.

1.1 DESIGN OF INPUT PAIR



Subject موضوع الدرس Date التاريخ

$\frac{g_m}{I_D} = \frac{160\mu}{10\mu} = 16$

From the specs $\Rightarrow A_{V_{DI}} > 34DB \Rightarrow 50$

$50 \Rightarrow 50 > \frac{g_m}{2g_{ds}} \Rightarrow \frac{g_m}{g_{ds}} > 100$

$g_{ds} < 1,6\mu S$

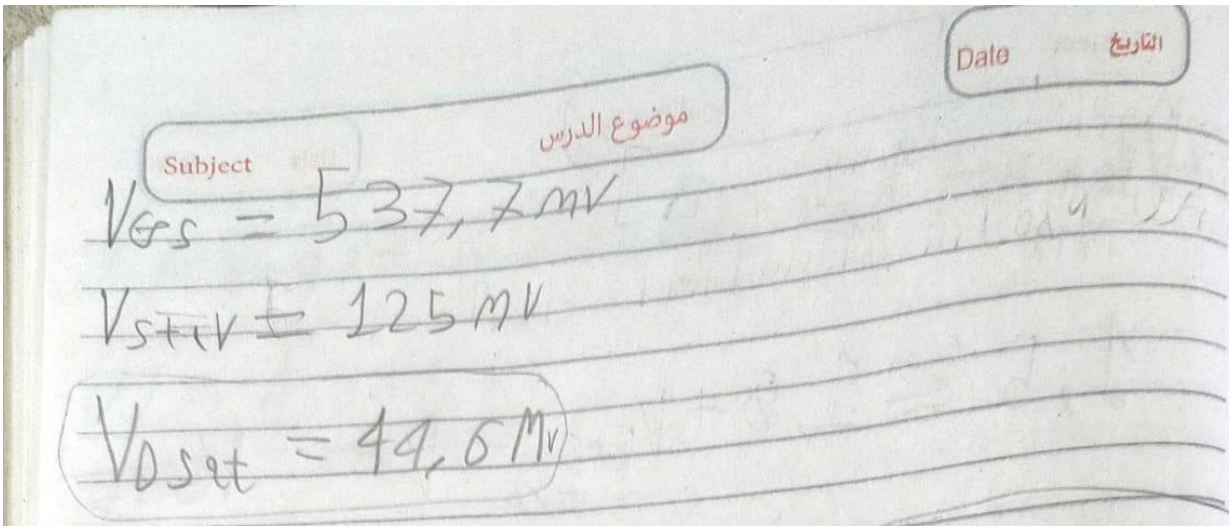
From the chart we found that the first L to give $g_{ds} < 1,6\mu S$

② $\frac{g_m}{I_D} = 16$ is $0,7\mu$

So we swept W Vs $\frac{G_M}{I_D}$ at constant $L = 0,7\mu$ and found $W = 4,057\mu$

We swept VGS 2 times one with considering body effect = 600mV, and another without

Elsalam


Date
التاريخ
Subject
موضوع الدرس
$V_{GS} = 537.7mV$
$V_{Stiv} = 125mV$
$V_{Dsat} = 44.6mV$

CHARTS:

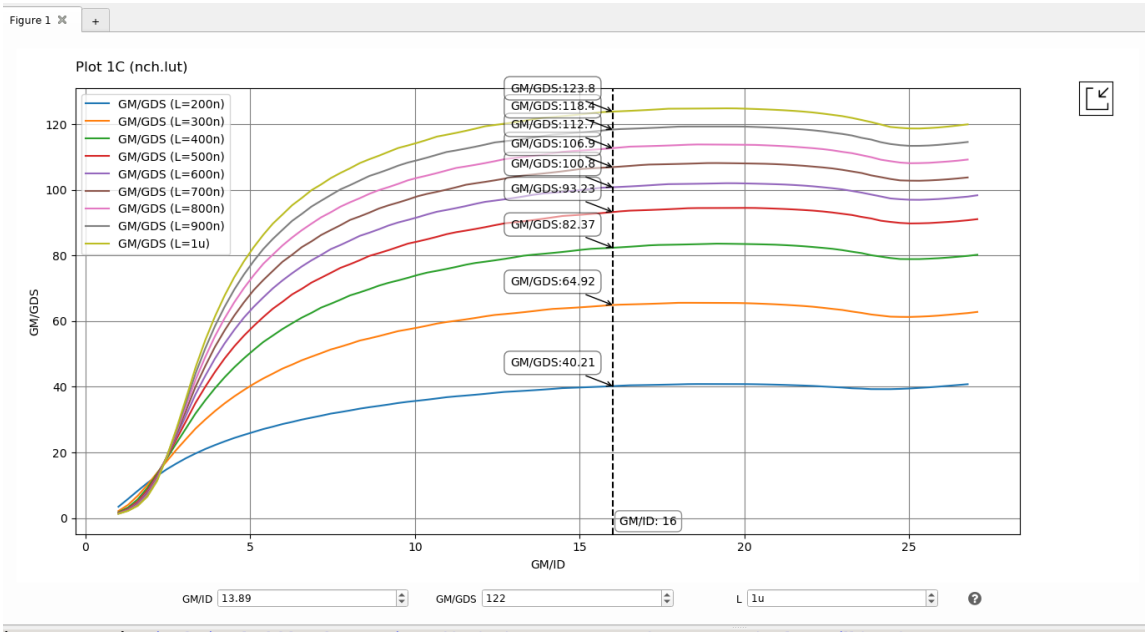
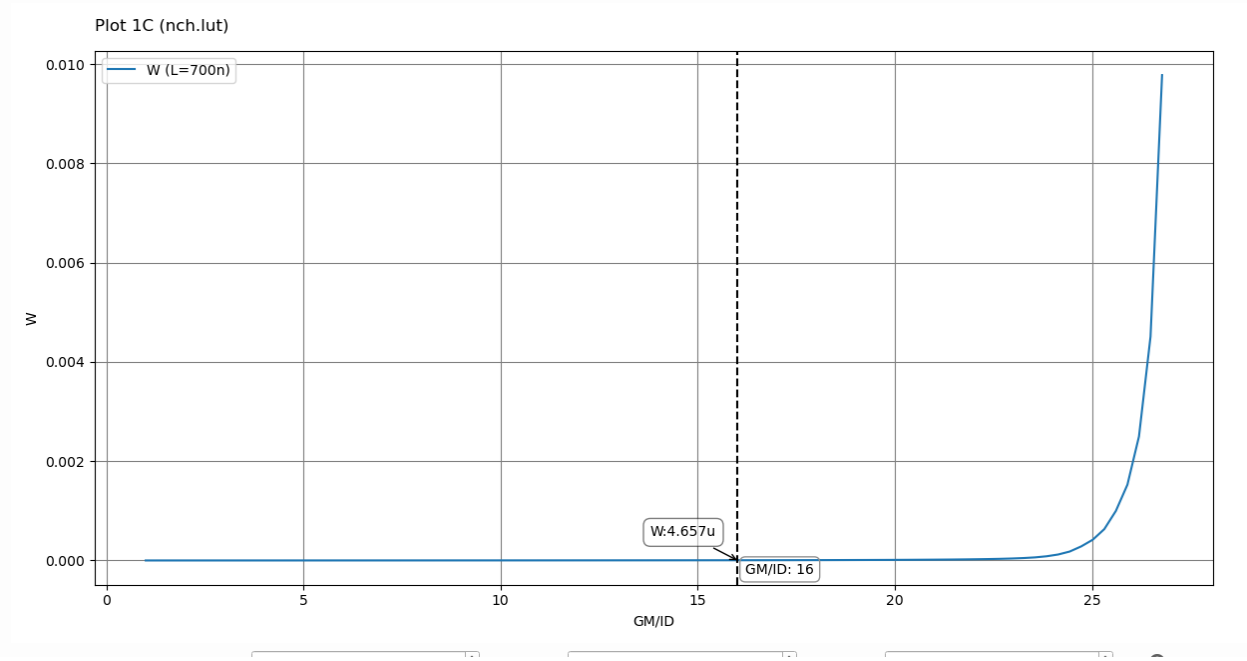
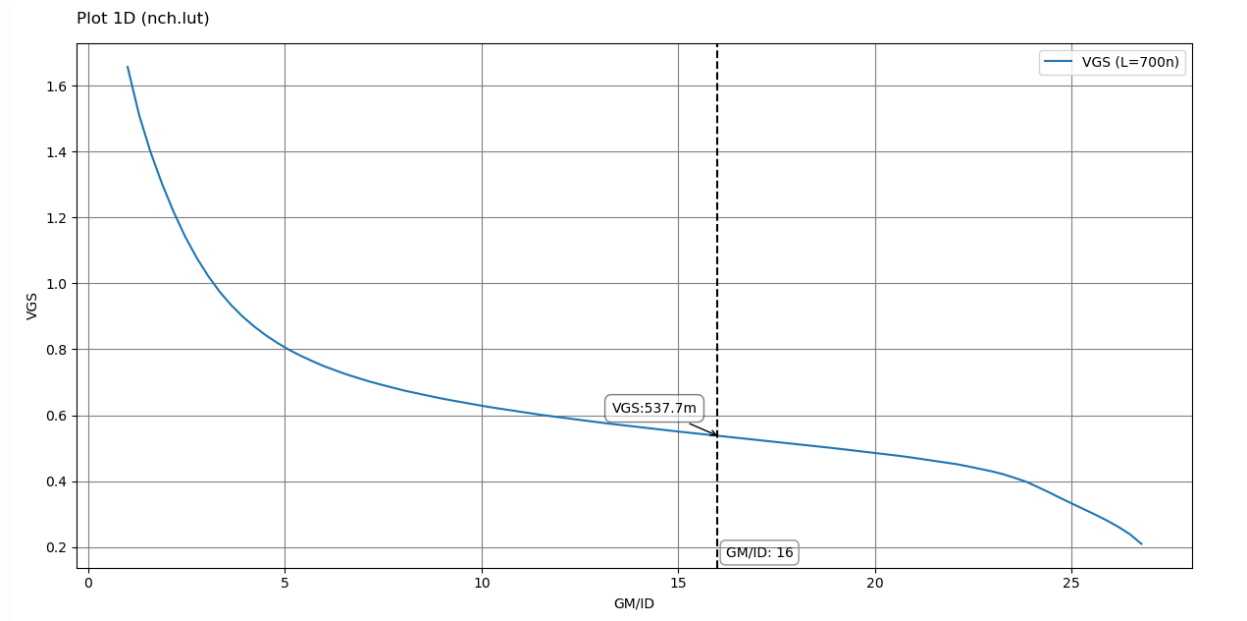


Figure 1
Plot 1C (nch.lut)
GM/GDS (L=200n)
GM/GDS (L=300n)
GM/GDS (L=400n)
GM/GDS (L=500n)
GM/GDS (L=600n)
GM/GDS (L=700n)
GM/GDS (L=800n)
GM/GDS (L=900n)
GM/GDS (L=1u)
GM/GDS:123.8
GM/GDS:118.4
GM/GDS:112.7
GM/GDS:106.9
GM/GDS:100.8
GM/GDS:93.23
GM/GDS:82.37
GM/GDS:64.92
GM/GDS:40.21
GM/ID: 16
GM/GDS
GM/ID
0
20
40
60
80
100
120
0
5
10
15
20
25
GM/ID 13.89
GM/GDS 122
L 1u


Plot 1C (nch.lut)
W (L=700n)
W
GM/ID
W:4.657u
GM/ID: 16
0.010
0.008
0.006
0.004
0.002
0.000
0
5
10
15
20
25


Plot 1D (nch.lut)
VGS (L=700n)
VGS
GM/ID
VGS:537.7m
GM/ID: 16
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25

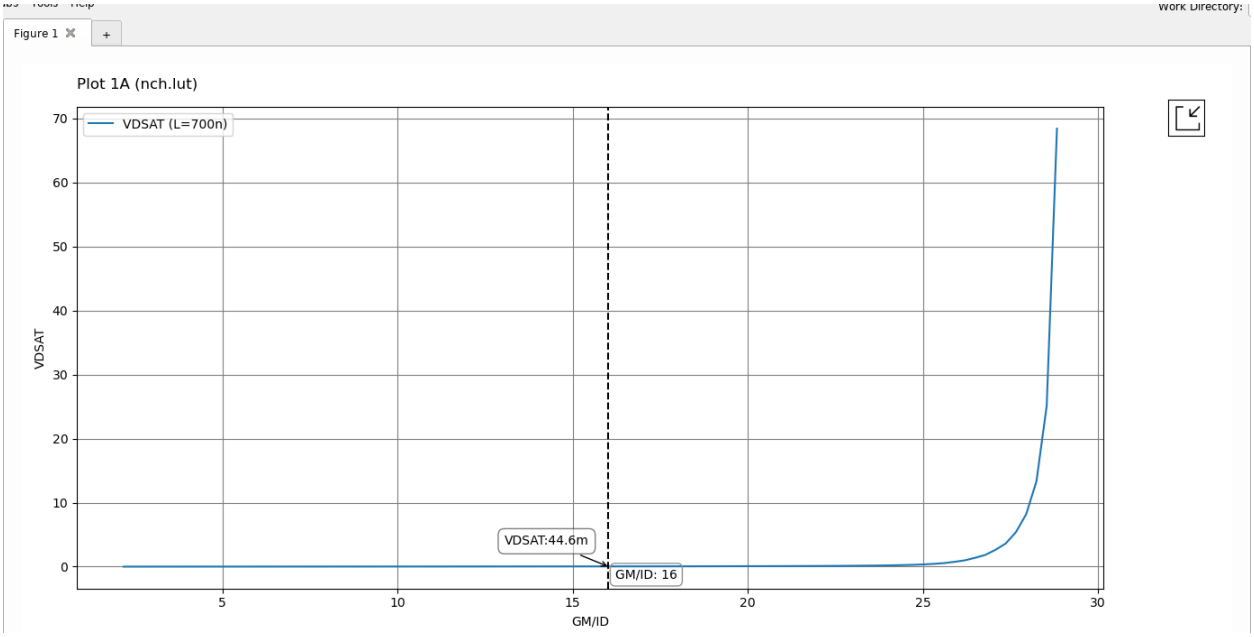
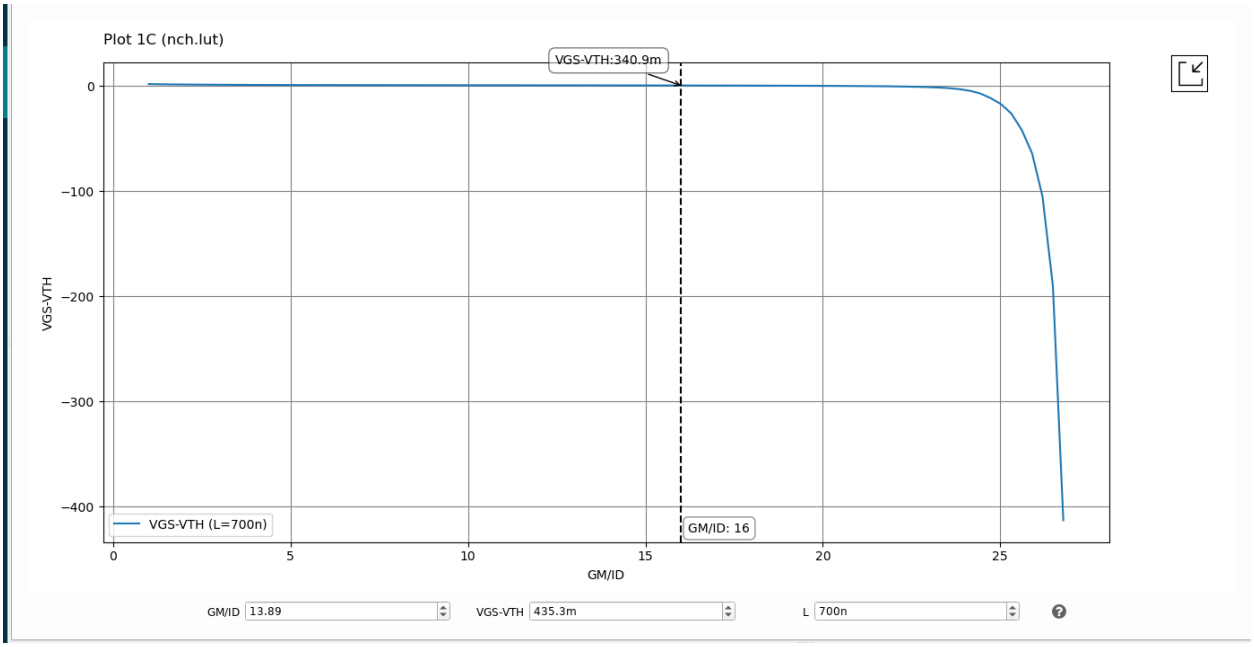
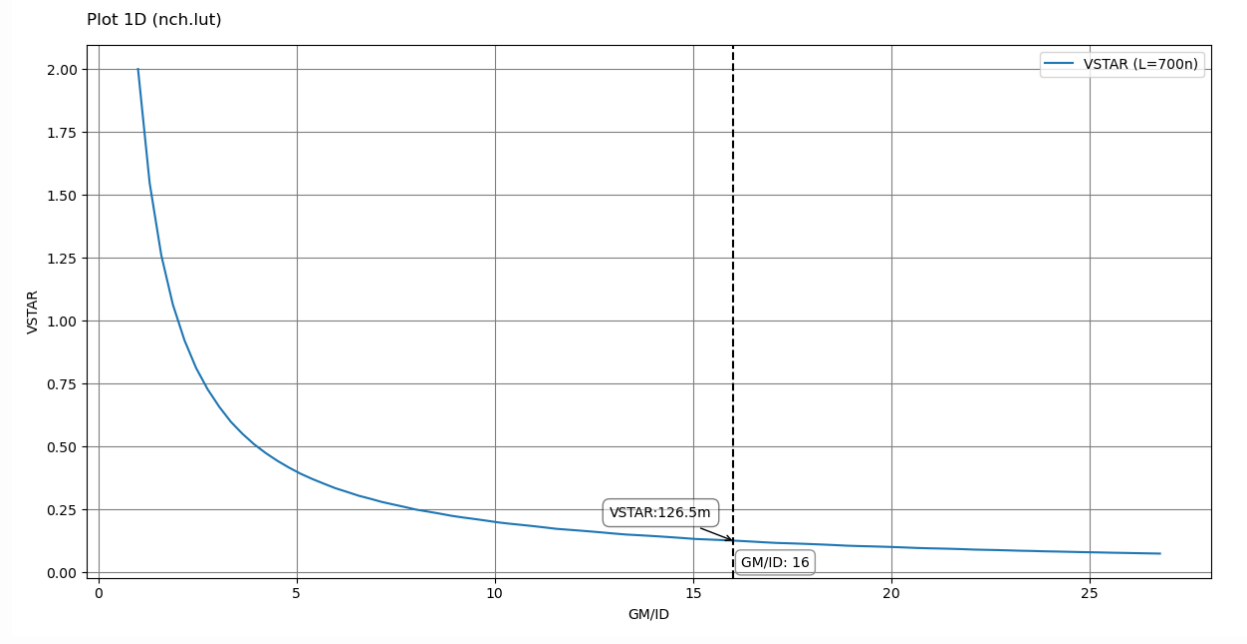
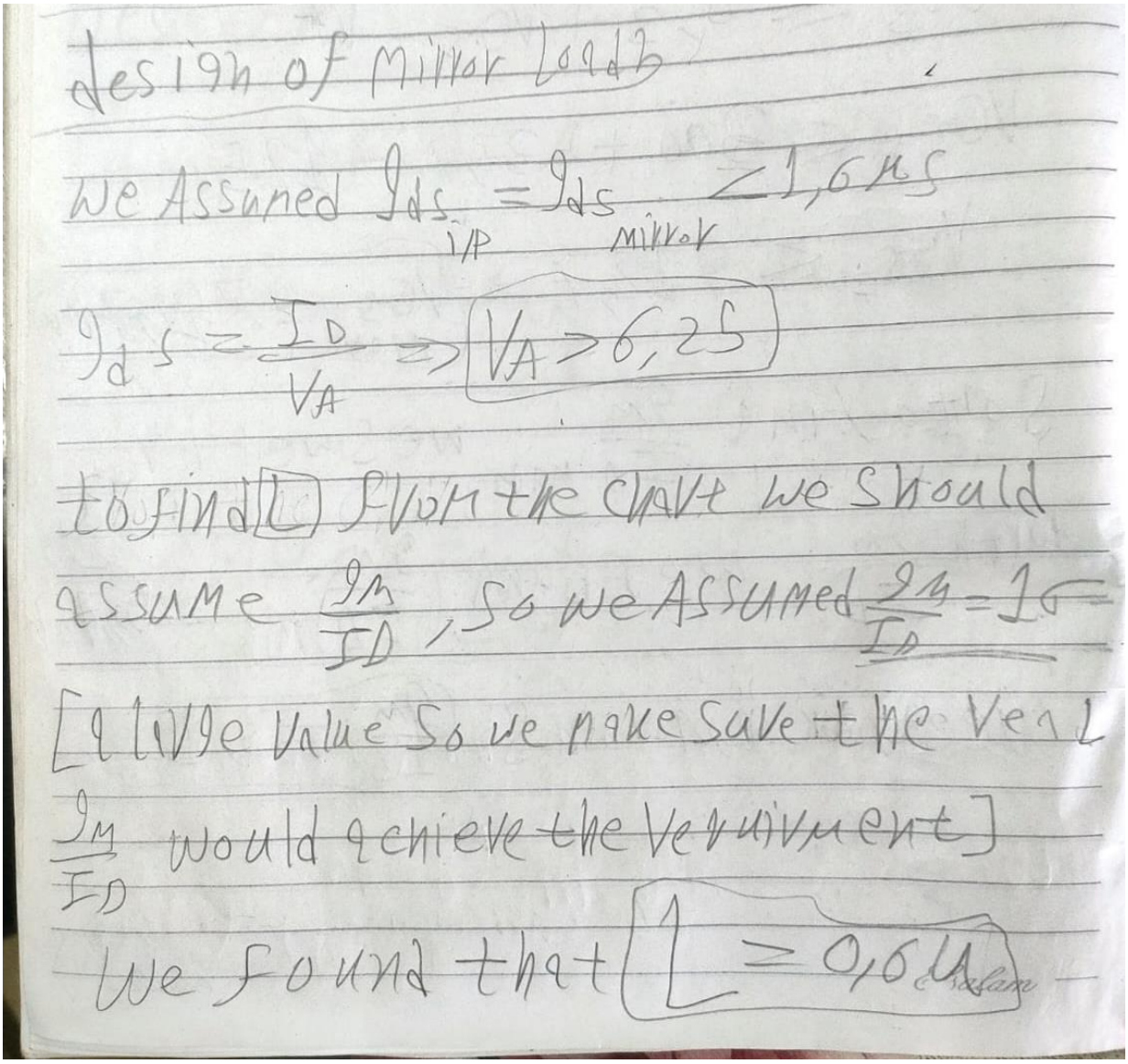


Figure 1
Plot 1A (nch.lut)
VDSAT (L=700n)
VDSAT
GM/ID
VDSAT:44.6m
GM/ID: 16


Plot 1C (nch.lut)
VGS-VTH:340.9m
VGS-VTH
GM/ID
VGS-VTH (L=700n)
GM/ID: 16
GM/ID 13.89
VGS-VTH 435.3m
L 700n


Plot 1D (nch.lut)
VSTAR (L=700n)
VSTAR
GM/ID
VSTAR:126.5m
GM/ID: 16
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
5
10
15
20
25

1.2 DESIGN OF MIRROR LOAD



Design of Mirror load

We Assumed $g_{ds_{I/P}} = g_{ds_{Mirror}} < 1,6\,mS$

$g_{ds} = \frac{I_D}{V_A} \Rightarrow V_A > 6,25$

to find L from the chart we should assume $\frac{g_m}{I_D}$, so we Assumed $\frac{g_m}{I_D} = 10$

[a little value so we make sure the real $\frac{g_m}{I_D}$ would achieve the requirement]

we found that $L = 0,6\,\mu m$

Subject موضوع الدرس

Date التاريخ

$V_{icm_{max}} >= 1,5$

$1,5 \leq 1,8 + V_{GS_{I/P}} - V^* - V_{GS_3}$

$V_{GS_3} \leq 0,3 + V_{GS} - V^*$

$V_{GS_3} \leq 300 + 537,7 - 125$

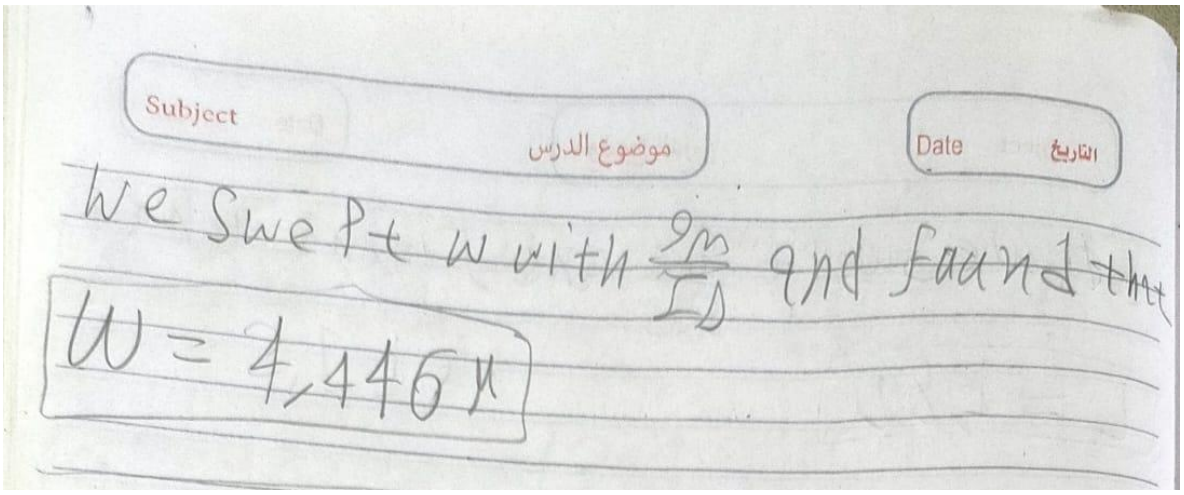
$V_{GS_3} \leq 712,7 \rightarrow V_{GS_{max}} = 712,7\,mV$

So to find $\frac{g_m}{I_D}_{min}$ we swept V_{GS}

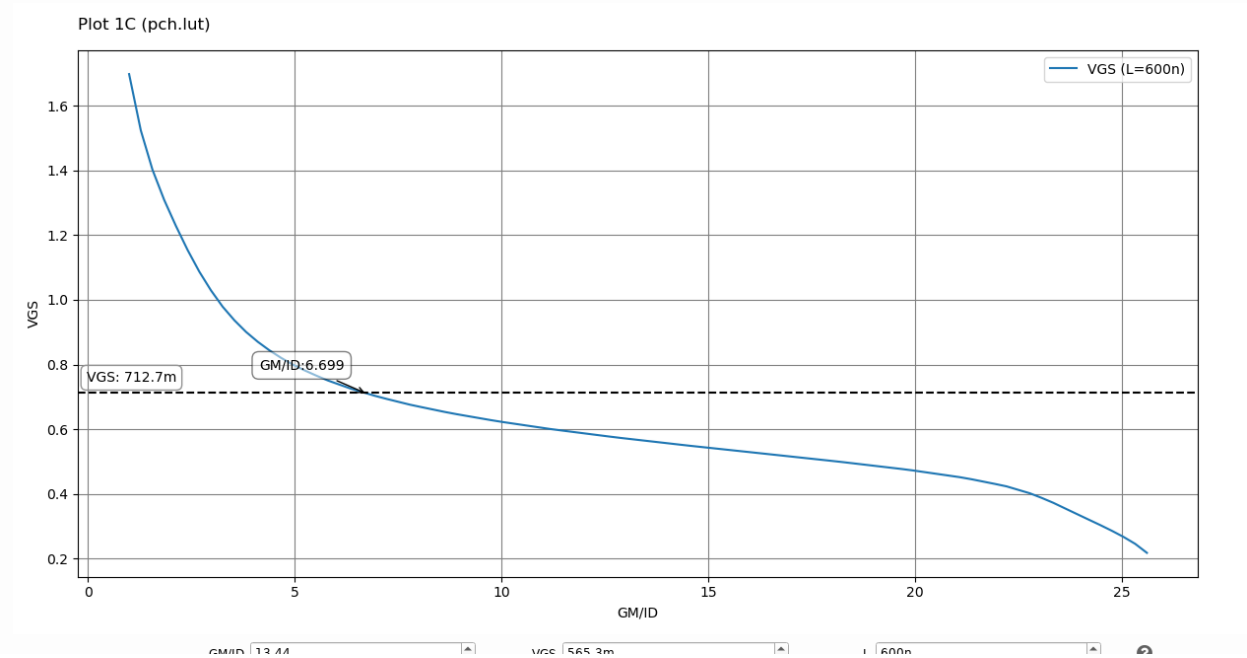
with $\frac{g_m}{I_D}$, we found $\left(\frac{g_m}{I_D}\right)_{min} = 6,7$

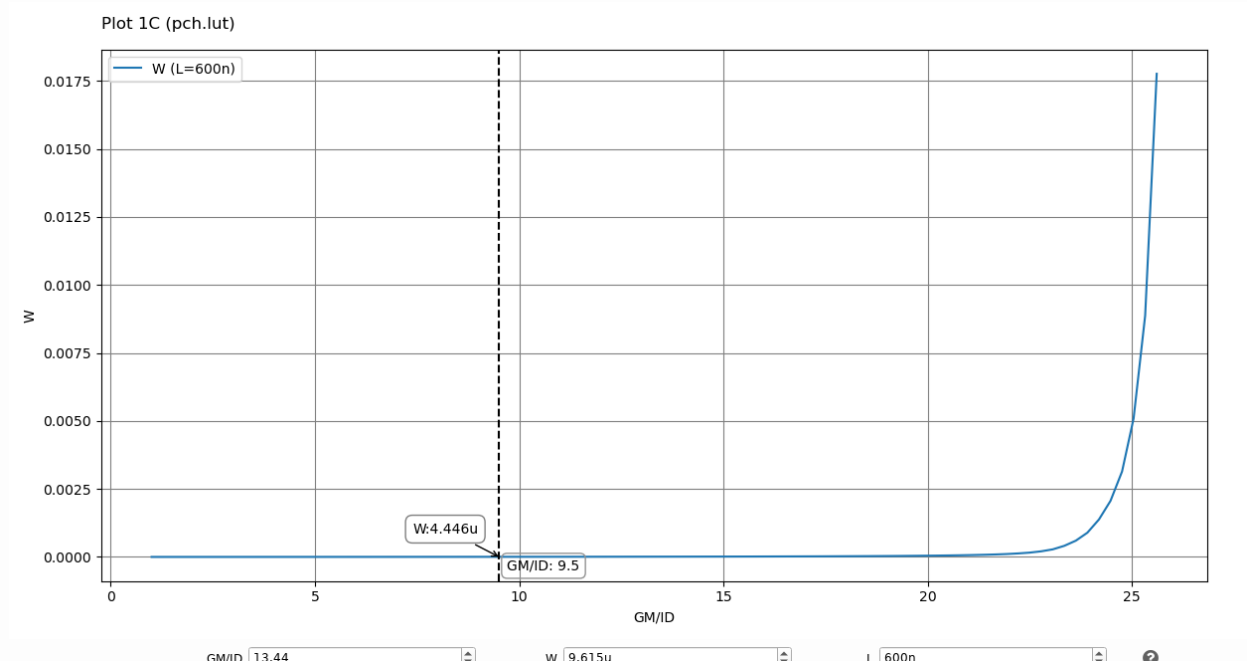
We took a margin So $\frac{g_m}{I_D} = 9,5$

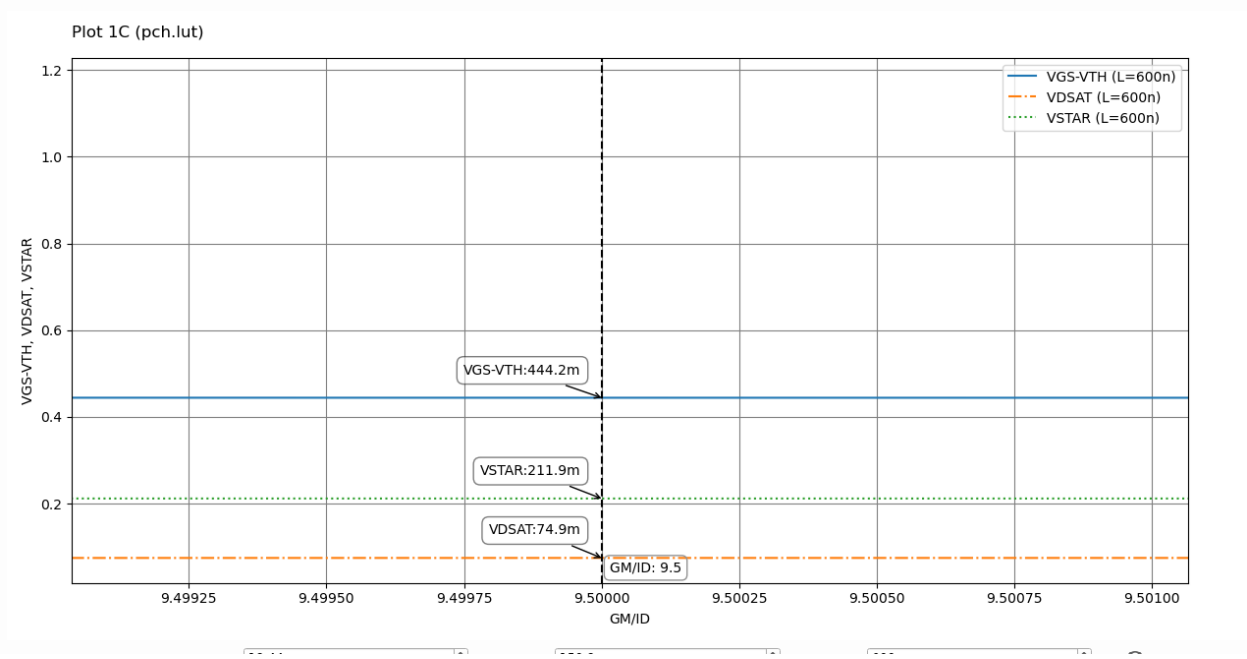
Elsalam


Subject
موضوع الدرس
Date
التاريخ
we Swept w with $\frac{g_m}{I_D}$ and found that
W = 4,446 n

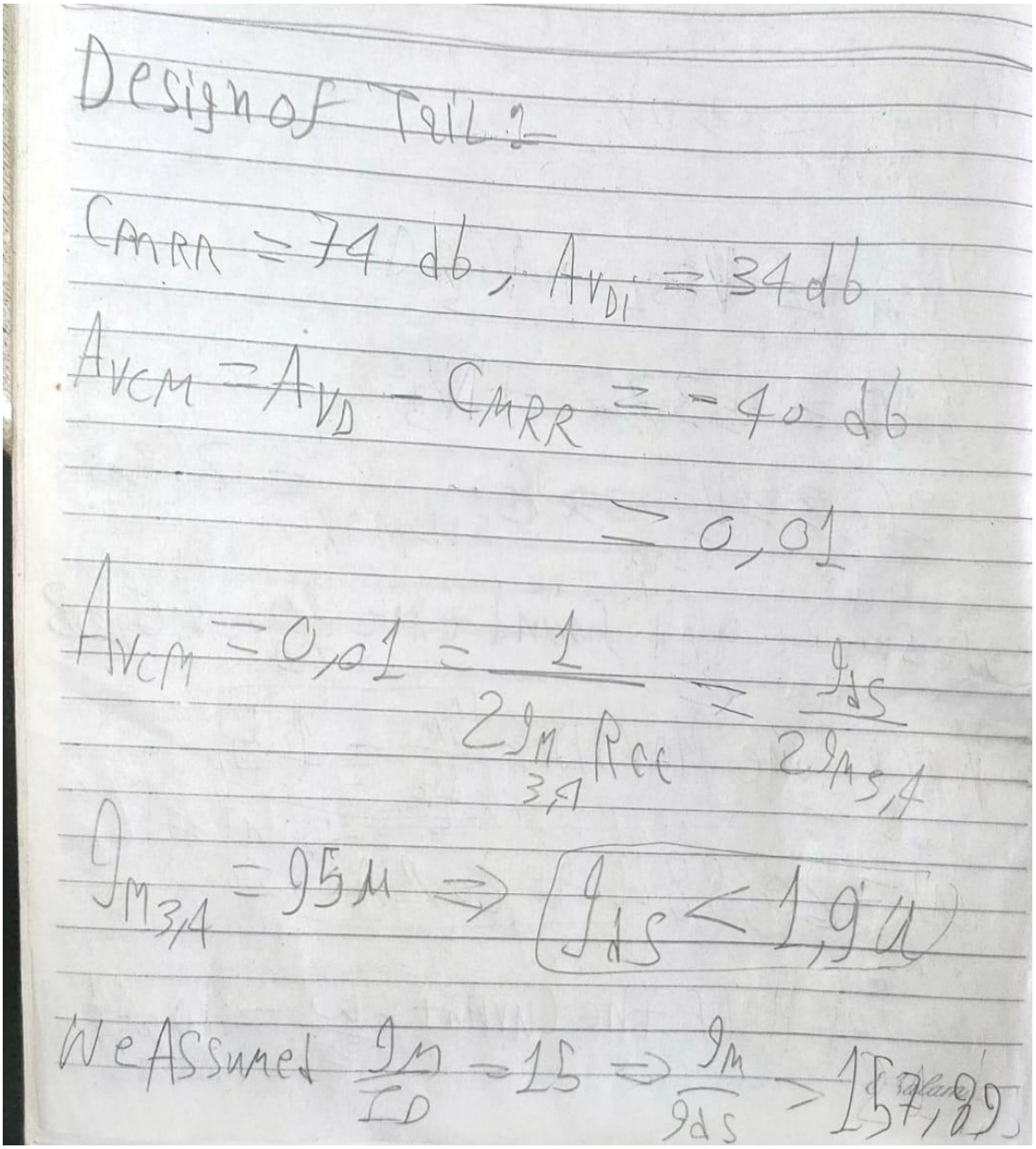
CHARTS:


Plot 1C (pch.lut)
VGS (L=600n)
VGS
GM/ID
VGS: 712.7m
GM/ID:6.699
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25


Plot 1C (pch.lut)
W (L=600n)
W
GM/ID
W:4.446u
GM/ID: 9.5
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
0
5
10
15
20
25
GM/ID 13.44
W 9.615u
600n


Plot 1C (pch.lut)
VGS-VTH (L=600n)
VDSAT (L=600n)
VSTAR (L=600n)
VGS-VTH, VDSAT, VSTAR
GM/ID
VGS-VTH:444.2m
VSTAR:211.9m
VDSAT:74.9m
GM/ID: 9.5
1.2
1.0
0.8
0.6
0.4
0.2
9.49925
9.49950
9.49975
9.50000
9.50025
9.50050
9.50075
9.50100

1.3 DESIGN OF TAIL CURRENT SOURCE



Subject موضوع الدرس Date التاريخ

So we swept $\frac{g_m}{2\pi s}$ and found that

$L = 1,8u$

$V_{in_{CM_{min}}} \geq 0,8V$

$V_{iCM} \geq V_{GS_1} + V_5$

$800 \geq 537,7 + V_5$

$262,3 \geq V_5 \Rightarrow V_{5_{SAT}} = 262,3$

$V_{5_{SAT_{MAX}}}$

We swept and found that $\frac{g_m}{I_D} = 16,53$

Keep some Margin: $\frac{g_m}{I_D} = 15$

$W = 20,88u$ at $20MA$

W for Half the Current $\frac{W}{2} = 10,44u$

Elbalam

CHARTS:

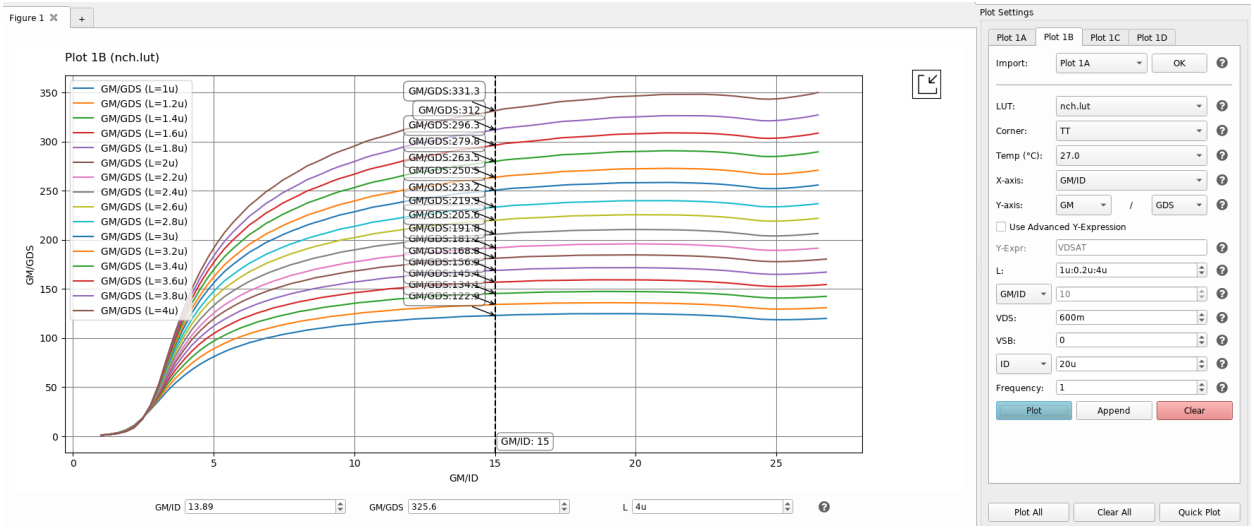
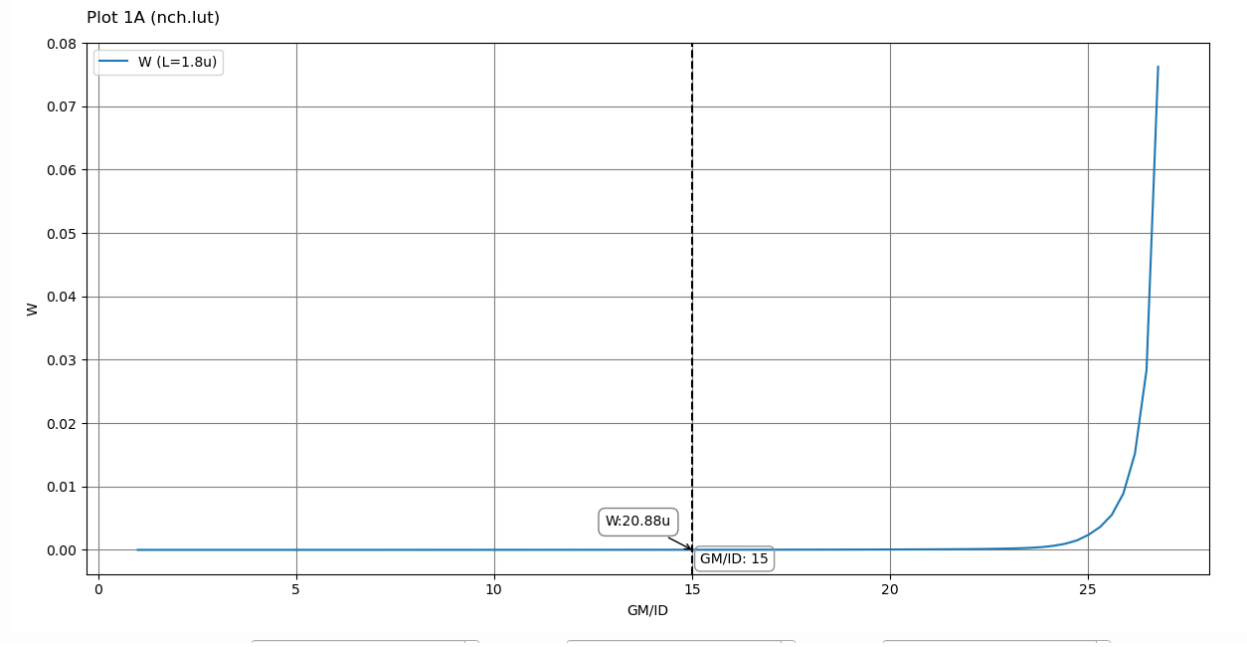
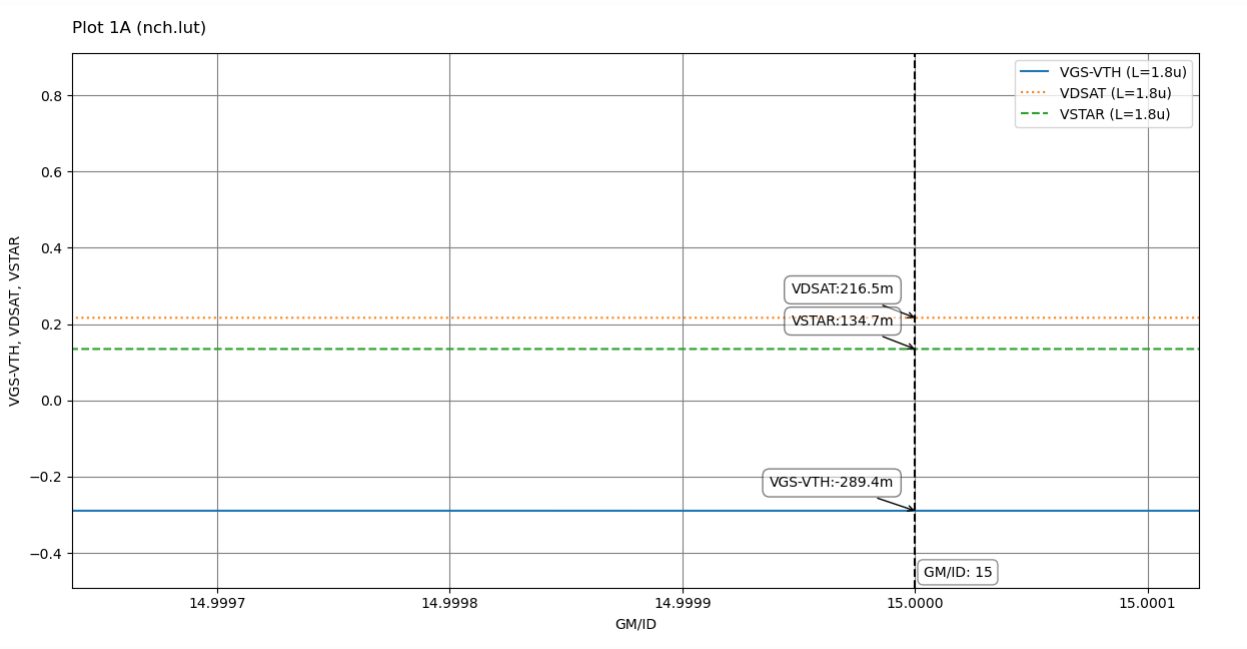


Figure 1
Plot 1B (nch.lut)
GM/GDS (L=1u)
GM/GDS (L=1.2u)
GM/GDS (L=1.4u)
GM/GDS (L=1.6u)
GM/GDS (L=1.8u)
GM/GDS (L=2u)
GM/GDS (L=2.2u)
GM/GDS (L=2.4u)
GM/GDS (L=2.6u)
GM/GDS (L=2.8u)
GM/GDS (L=3u)
GM/GDS (L=3.2u)
GM/GDS (L=3.4u)
GM/GDS (L=3.6u)
GM/GDS (L=3.8u)
GM/GDS (L=4u)
GM/GDS:331.3
GM/GDS:312
GM/GDS:296.3
GM/GDS:279.8
GM/GDS:263.5
GM/GDS:250.5
GM/GDS:233.2
GM/GDS:219.9
GM/GDS:205.6
GM/GDS:191.8
GM/GDS:181.2
GM/GDS:168.8
GM/GDS:156.4
GM/GDS:145.4
GM/GDS:134.1
GM/GDS:122.9
GM/ID: 15
GM/GDS
GM/ID
GM/ID 13.89
GM/GDS 325.6
L 4u
Plot Settings
Plot 1A
Plot 1B
Plot 1C
Plot 1D
Import:
Plot 1A
OK
LUT:
nch.lut
Corner:
TT
Temp (°C):
27.0
X-axis:
GM/ID
Y-axis:
GM
GDS
Use Advanced Y-Expression
Y-Expr:
VDSAT
L:
1u:0.2u:4u
GM/ID
10
VDS:
600m
VSB:
0
ID
20u
Frequency:
1
Plot
Append
Clear
Plot All
Clear All
Quick Plot


Plot 1A (nch.lut)
W (L=1.8u)
W:20.88u
GM/ID: 15
W
GM/ID

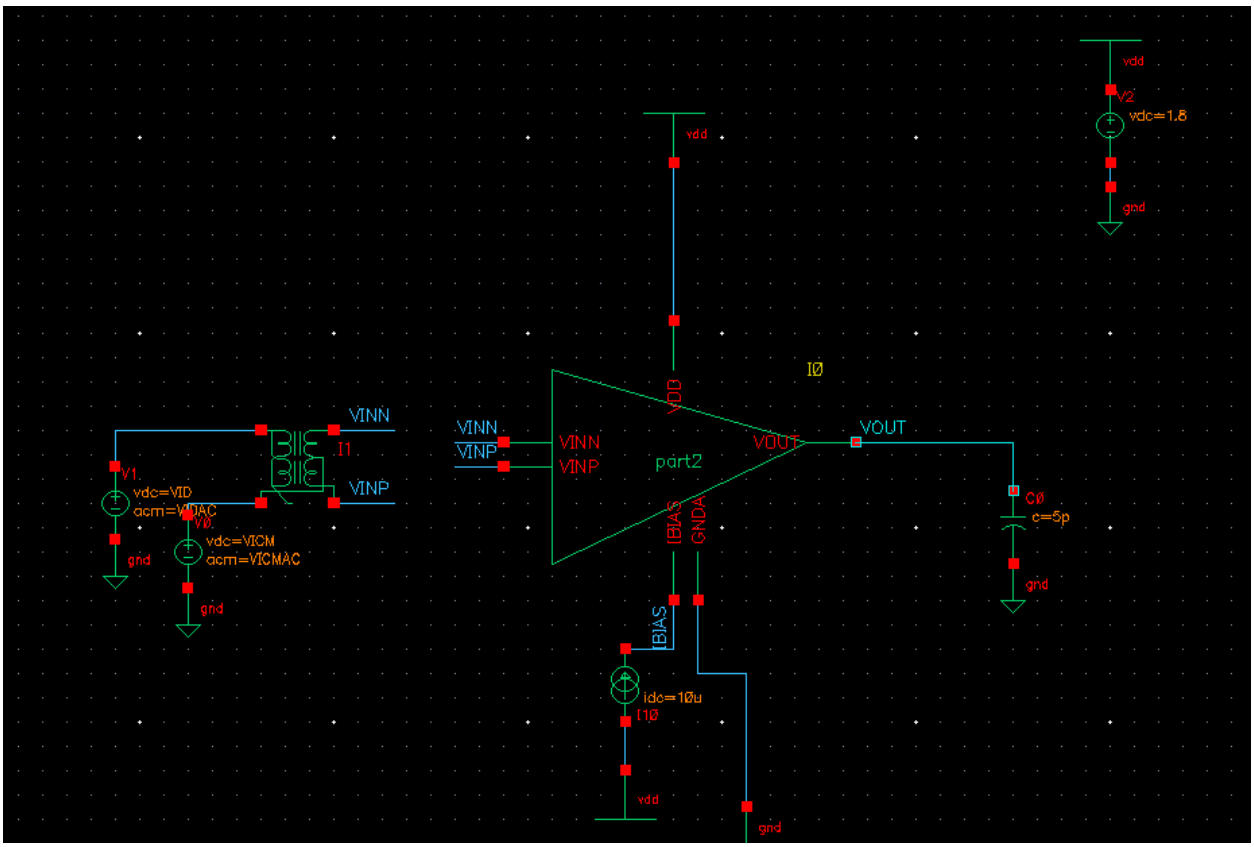


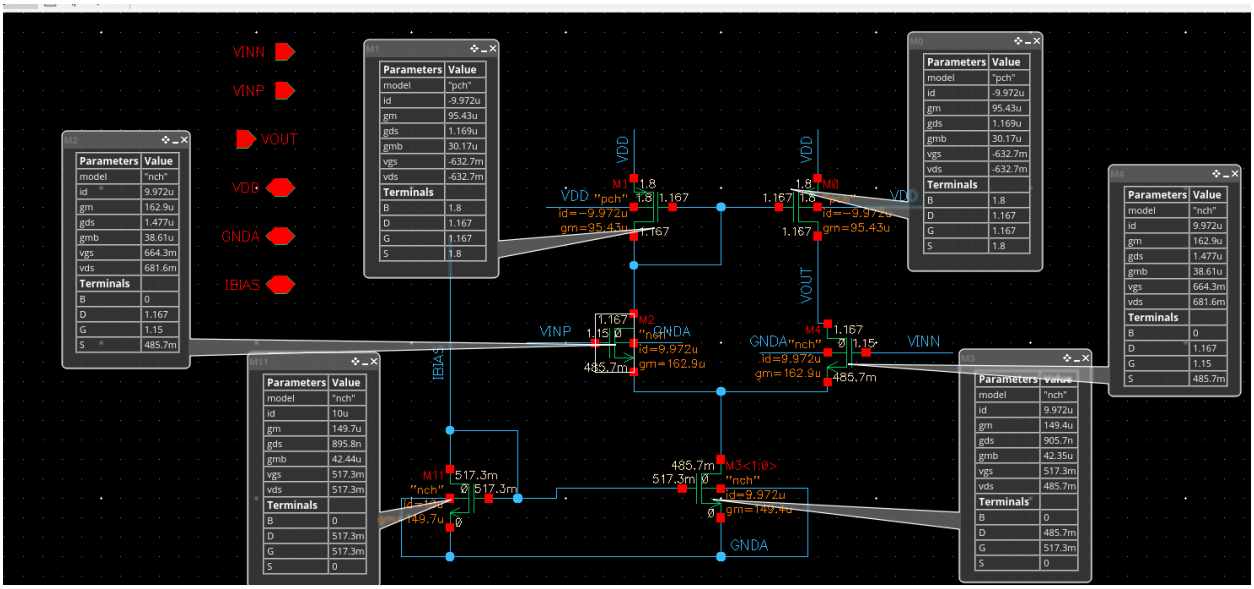
2 A TABLE SHOWING W, L, gm,ID, gm/ID, $VDSsat$, $Vov = VGS - VTH$, AND $V* = 2ID/gm$ OF ALL TRANSISTORS (AS CALCULATED FROM G M/ID CURVES)

TRANS	W	L	GM	ID	GM/ID	VDSsat	VOV	VSTAR
Input pair	4.657u	0.7u	160u	10u	16	44.6m	340.9m	125m
MIRROR LOAD	4.446u	0.6u	95u	10u	9.5	74.9m	444.2m	211.9m
TAIL CURRENT SOURCE	**with 20u** 20.88 **with 10u** 10.44u	1.8u	300u	20u	15	216.5m	-298.4m	134.7m

PART3

1 SCHEMATIC OF THE OTA WITH DC NODE VOLTAGES CLEARLY ANNOTATED





The tail current source transistor is made of array of two transistors and the sizing shown is of one of the unit transistor of them.

1.1 USE VICM AT THE MIDDLE OF THE CMIR.

(1.5+0.8)/2=1.15V

1.2 IS THE CURRENT (AND GM) IN THE INPUT PAIR EXACTLY EQUAL?

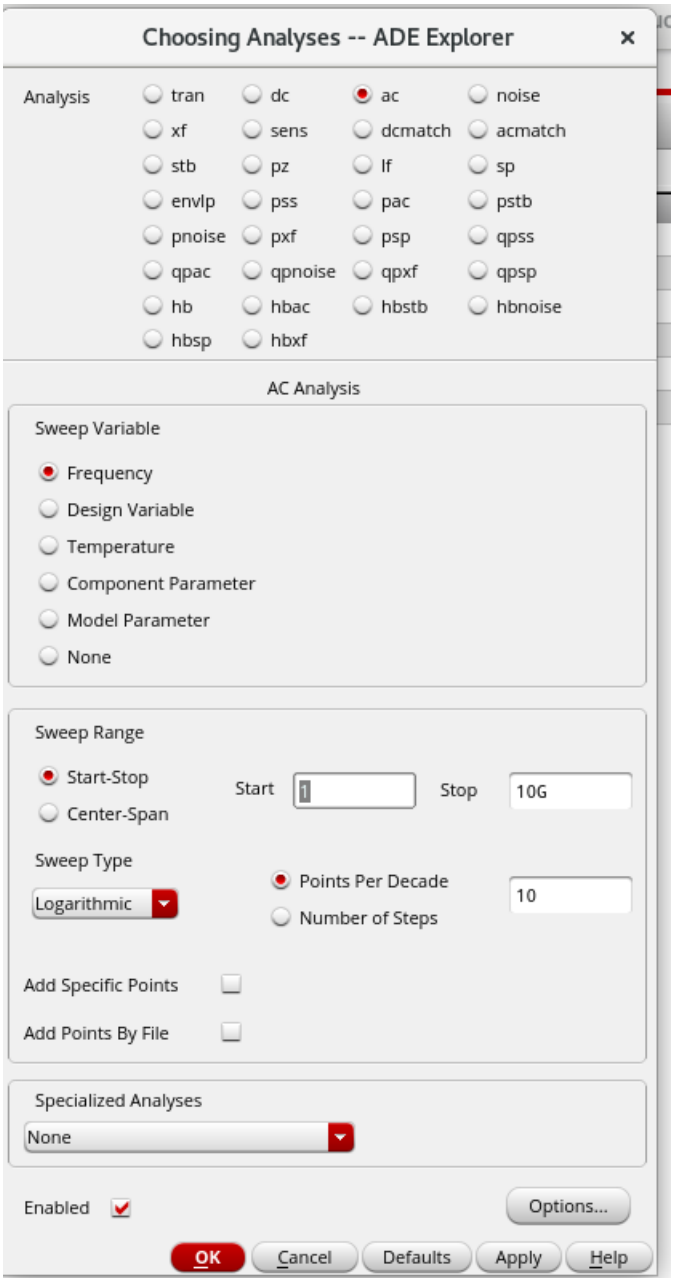
YES, id=9.972u gm=162.9u

1.3 WHAT IS DC VOLTAGE AT VOUT? WHY?

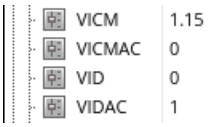
1.167v,as VOUT=VDD-VGS(0) and M0 follow M1 and it is diode connected so VGS(0)=VGS(1)=VDS, 1.8-0.632=1.167 V

2 DIFF SMALL SIGNAL CCS:

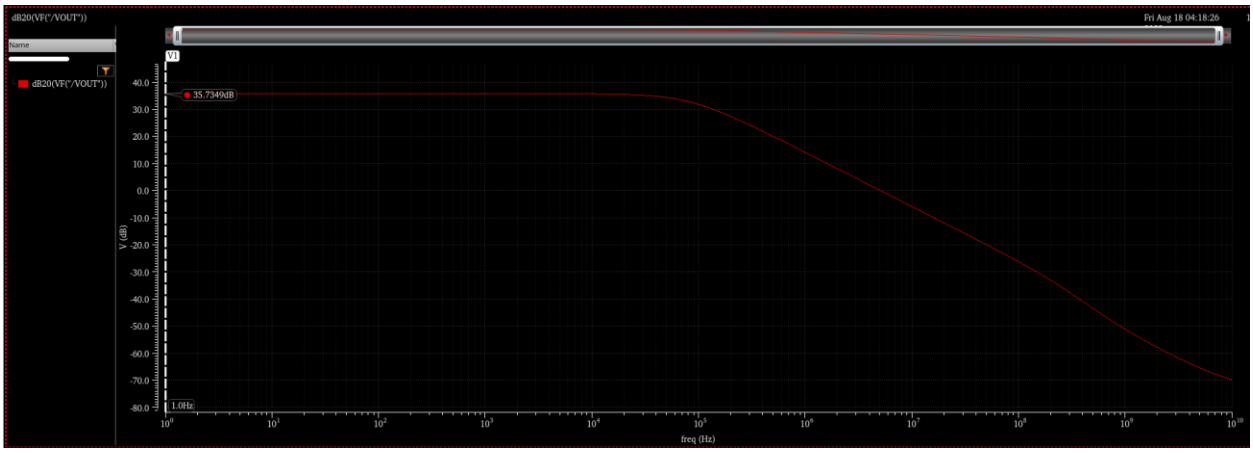
2.1 USE AC ANALYSIS (1HZ:10GHZ, LOGARITHMIC, 10 POINTS/DECADE).



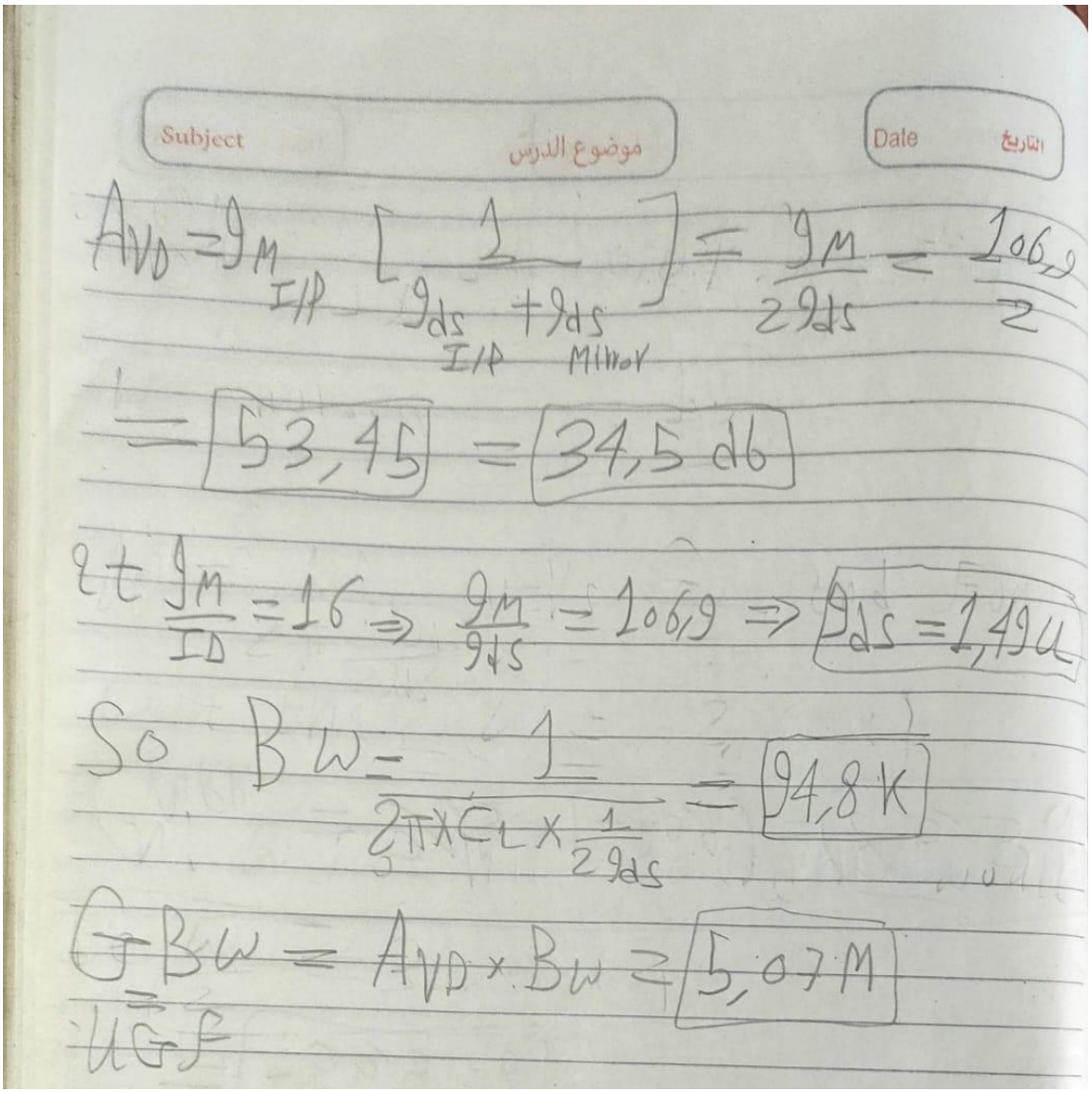
2.2 SET VIDAC = 1 AND VICMAC = 0 & USE VICM AT THE MIDDLE OF THE CMIR.



2.3 PLOT DIFF GAIN (IN DB) VS FREQUENCY.



2.4 COMPARE SIMULATION RESULTS WITH HAND CALCULATIONS IN A TABLE

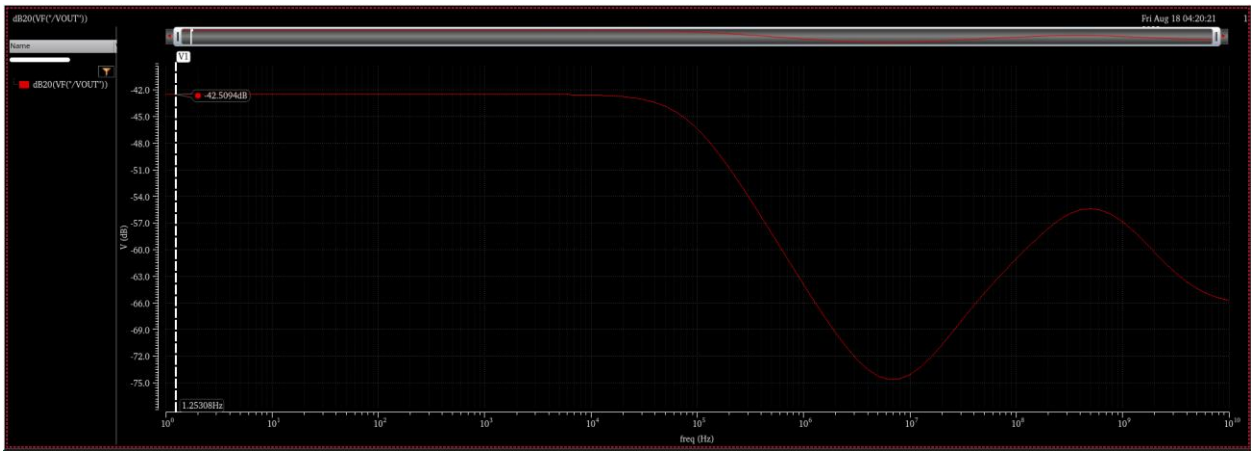


lab7_part234_1	AO	61.2			
lab7_part234_1	AO_DB	35.73			
lab7_part234_1	BW	83.35K			
lab7_part234_1	fu	5.12M			
lab7_part234_1	GBW	5.101M			
lab7_part234_1	dB20(VF("/VOUT...				

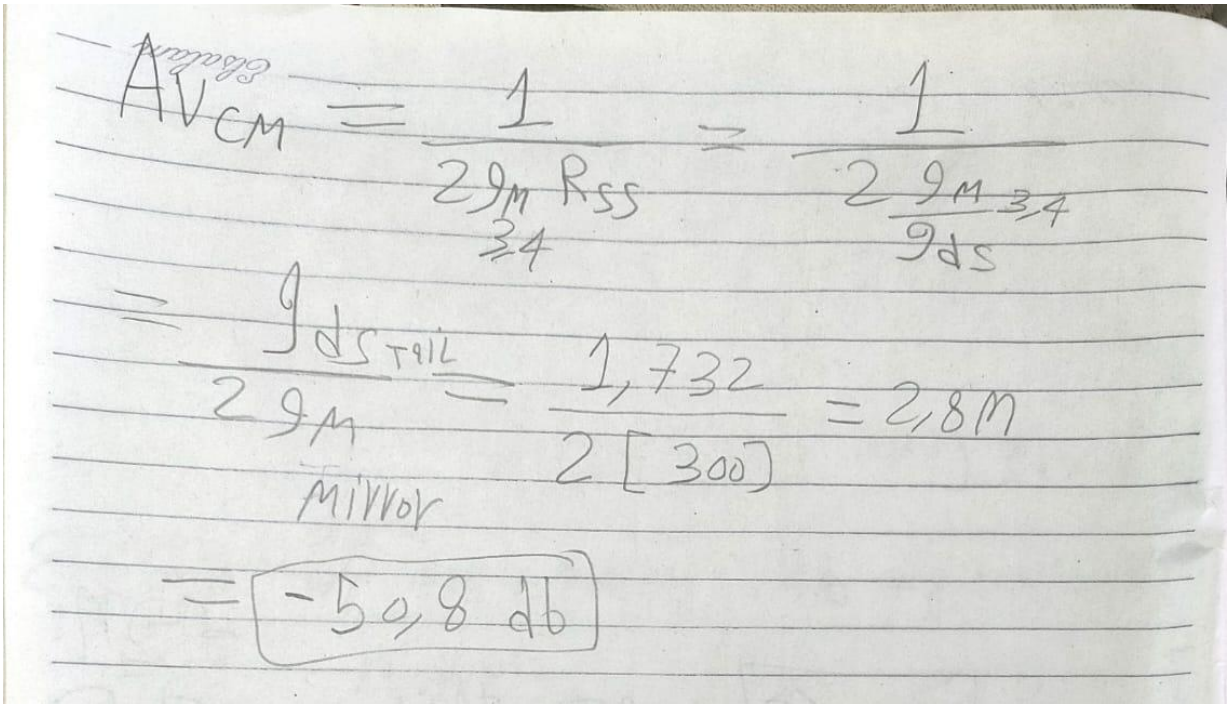
	simulated	Analytical
A0	61.2	53.45
A0_DB	35.73 db	34.5 db
BW	83.35k	94.8k
GBW	5.12M	5.07M
Fu	51.01M	5.07M

3 CM SMALL SIGNAL CCS

3.1 PLOT CM GAIN IN DB VS FREQUENCY.



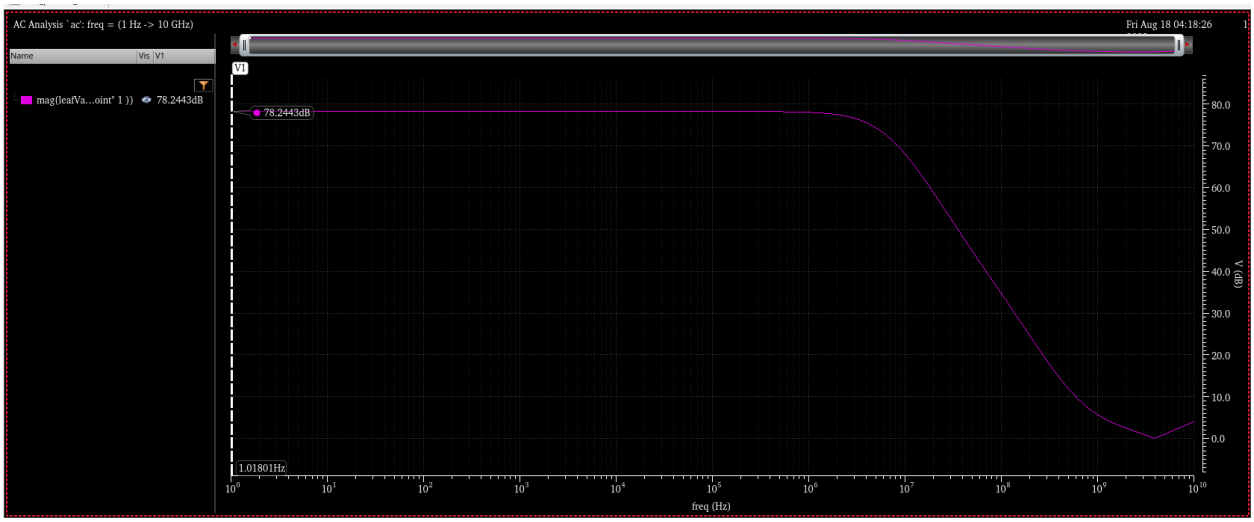
3.2 COMPARE SIMULATION RESULTS WITH HAND CALCULATIONS IN A TABLE.



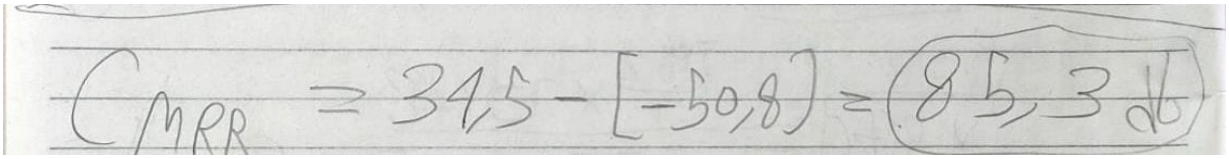
	SIMULATOR	ANALYTICAL
AVCM	-42.8 db	-50.8 db

4 CMRR:

4.1 PLOT CMRR IN DB VS FREQUENCY AT VICM AT THE MIDDLE OF THE CMIR.



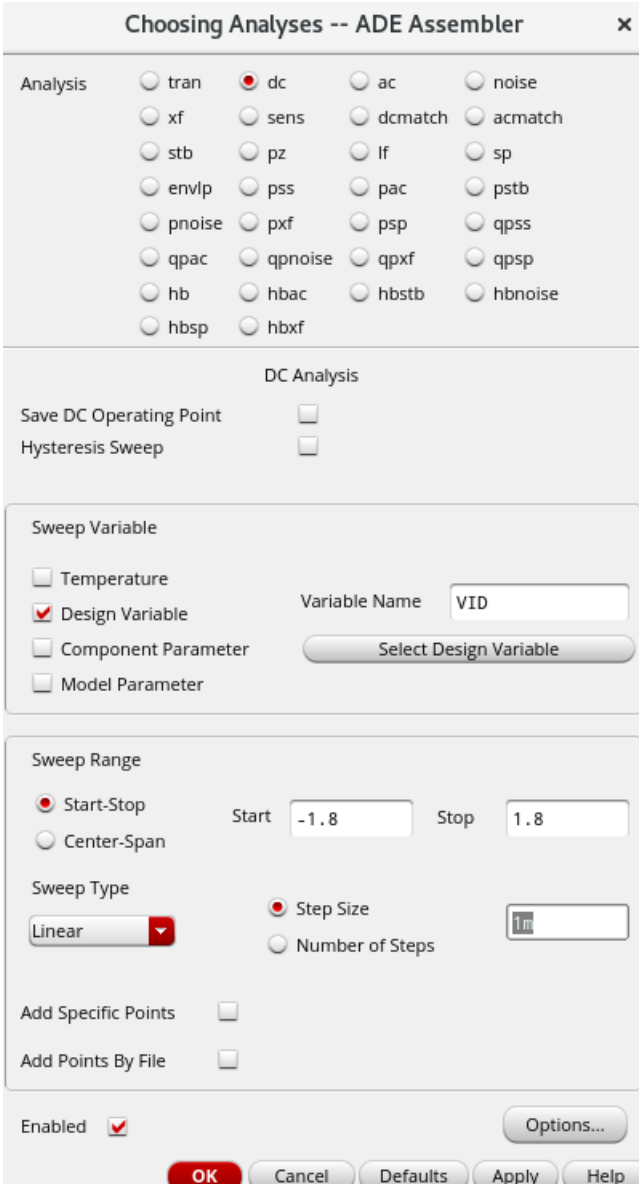
4.2 COMPARE SIMULATION RESULTS WITH HAND CALCULATIONS IN A TABLE.



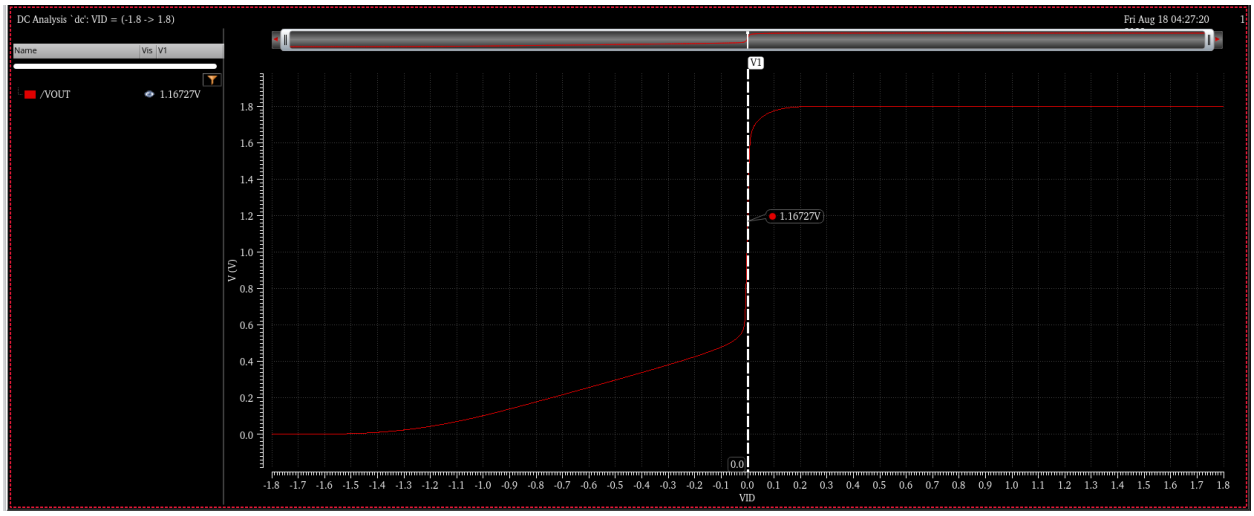
	SIMULATOR	ANALYTICAL
CMRR	78.24 db	85.3 db

5 DIFF LARGE SIGNAL CCS:

5.1 USE DC SWEEP (NOT PARAMETRIC SWEEP) VID = -VDD:1M:VDD. YOU MUST USE A SMALL STEP (1MV) BECAUSE THE GAIN REGION IS VERY SMALL (STEEP SLOPE).



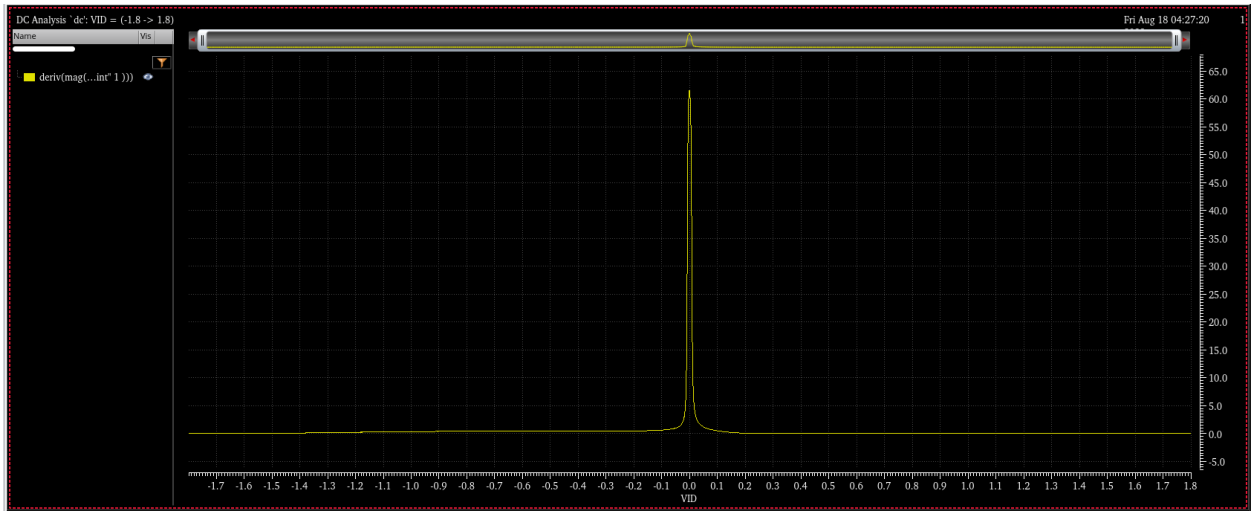
5.2 PLOT VOUT VS VID.



5.3 FROM THE PLOT, WHAT IS THE VALUE OF VOUT AT VID = 0? WHY?

1.167 , Which is the dc operating point (vicm) as VID=0, the current is equal in the two halves at this point so Vout follow Vf.

5.4 PLOT THE DERIVATIVE OF VOUT VS VID. COMPARE THE PEAK WSOITH AVD.

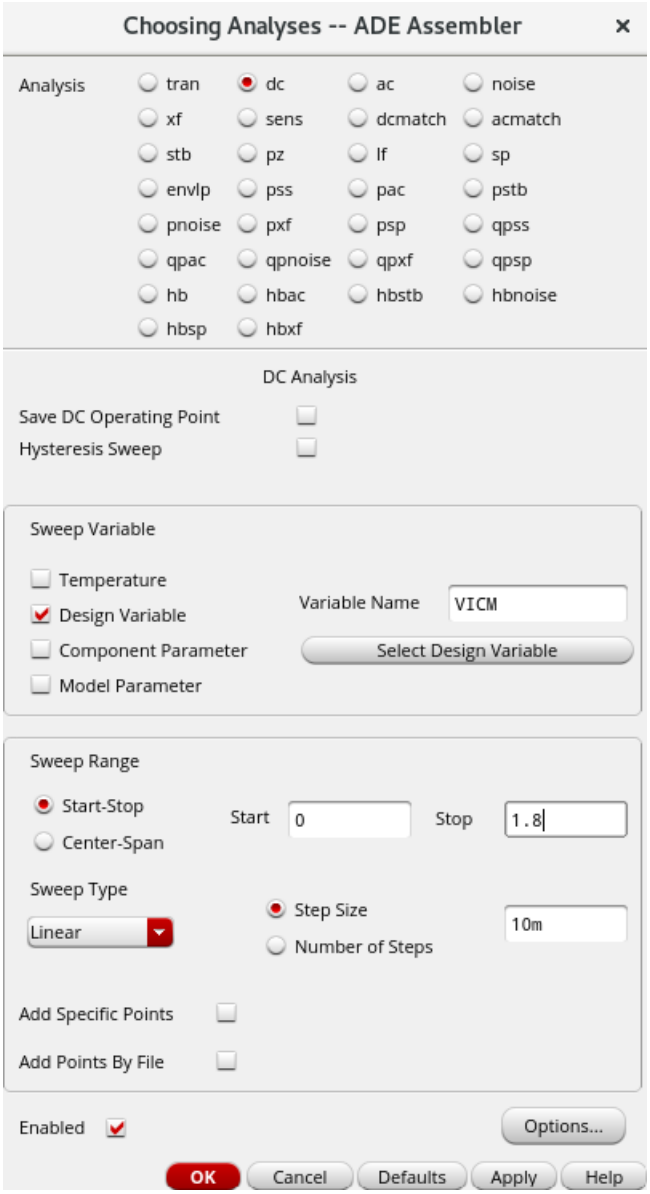


	Expression	Value
1	ymax(deriv(mag...	61.55

Here is the peak is 61.55, but Avd=61.2

6 CM LARGE SIGNAL CCS (REGION VS VICM):

6.1 USE DC SWEEP (NOT PARAMETRIC SWEEP) VICM = 0:10M:VDD.



6.2 PLOT "REGION" OP PARAMETER VS VICM FOR THE INPUT PAIR AND THE TAIL CURRENT SOURCE.

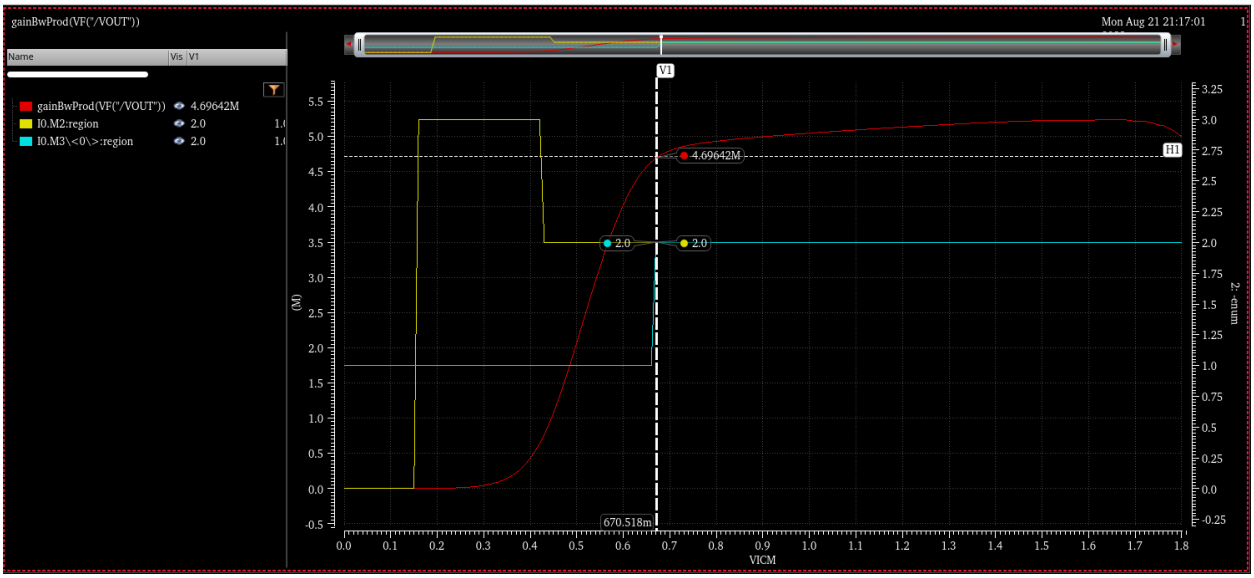
6.3 FIND THE CM INPUT RANGE (CMIR). COMPARE WITH HAND ANALYSIS IN A TABLE.

1.8-670.79m=1.13 V

HAND ANALYSIS: 1.5-0.8=0.7 V

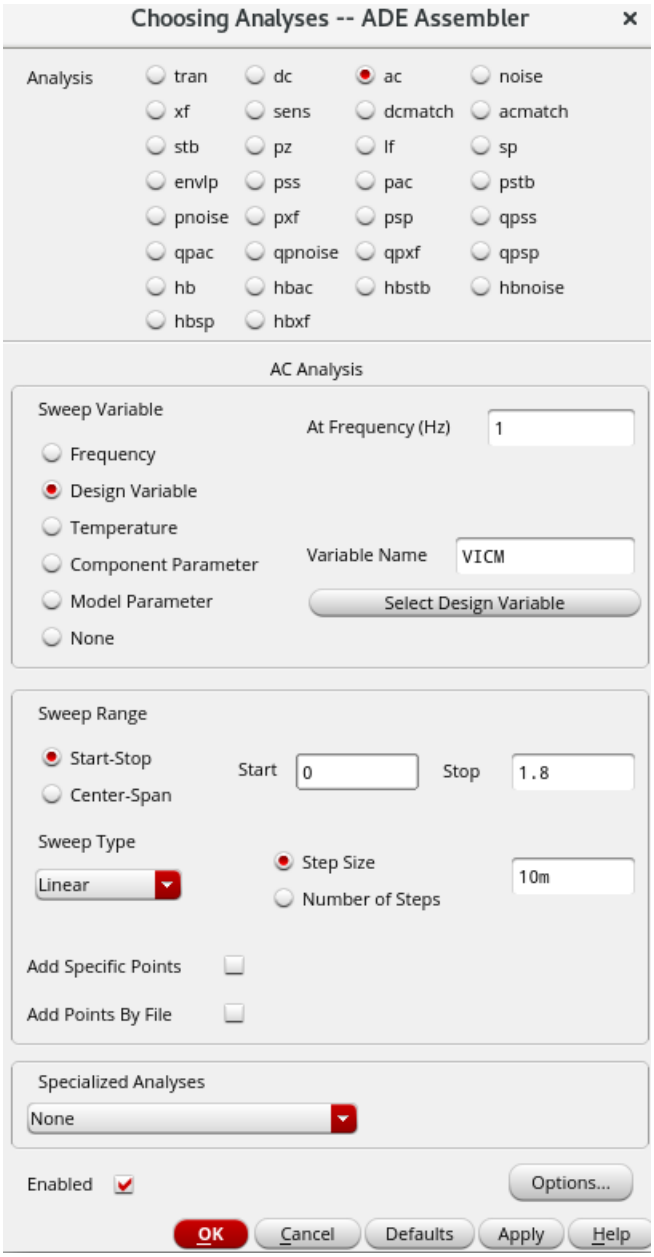
	sim	Hand analysis
CMIR	1.13	0.7

6.4 PLOT "REGION" OP PARAMETER VS VICM FOR THE INPUT PAIR AND THE TAIL CURRENT SOURCE (0 CUT-OFF, 1 TRIODE, 2 SAT, 3 SUBTH, AND 4 BREAKDOWN). PLOT THE RESULTS OVERLAID ON THE RESULTS OF THE PREVIOUS METHOD (10% REDUCTION OF GBW).

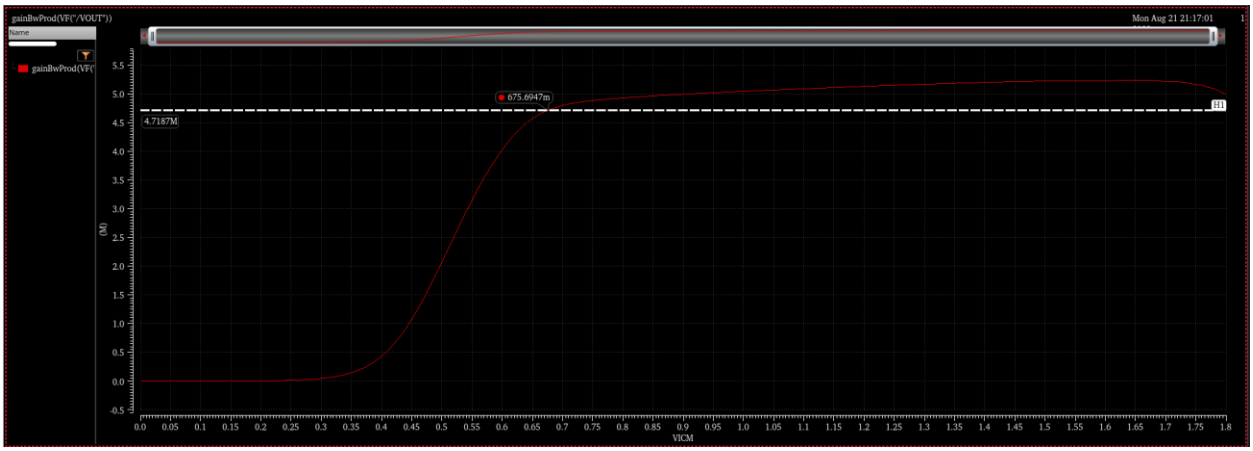


7 (OPTIONAL) CM LARGE SIGNAL CCS (GBW VS VICM)

7.1



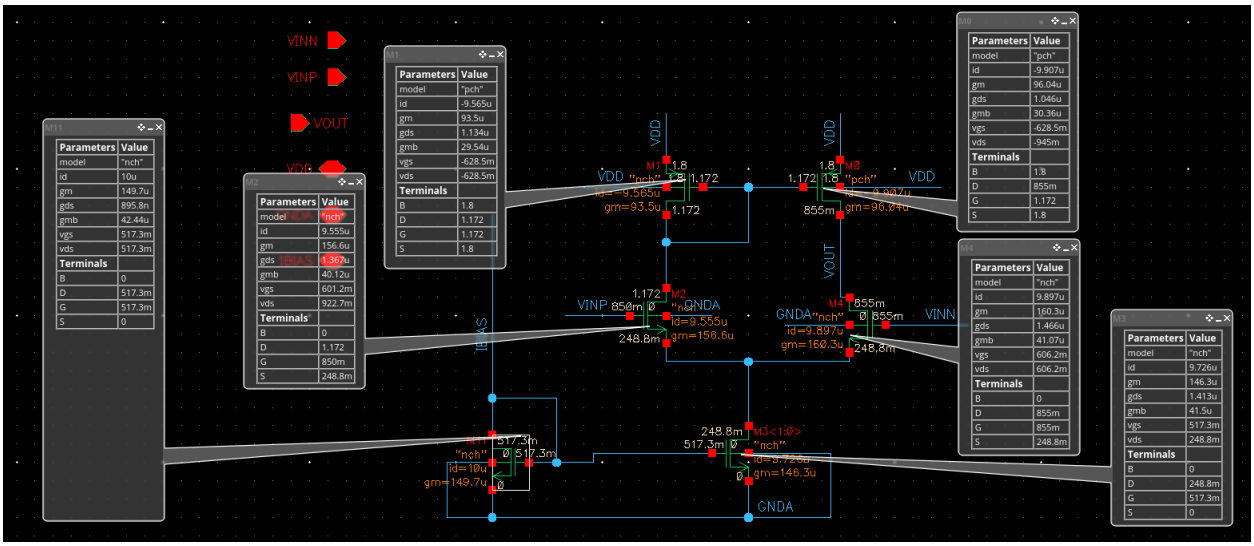
7.2 ANNOTATE THE CM INPUT RANGE. CALCULATE THE INPUT RANGE AS THE RANGE OVER WHICH THE GBW IS WITHIN 90% OF THE MAX GBW, I.E., 10% REDUCTION IN GBW2 .



The input range= 1.8-0.676=1.124 V

Part4:

1 SCHEMATIC OF THE OTA WITH DC OP POINT CLEARLY ANNOTATED IN UNITY GAIN BUFFER CONFIGURATION. USE VIN = CMIR-LOW + 50MV.



1.1 IS THE CURRENT (AND GM) IN THE INPUT PAIR EXACTLY EQUAL ? WHY?

NO, because of the feedback make The output voltage deviates from its CM level Since the gain is finite (Verror=5mv)

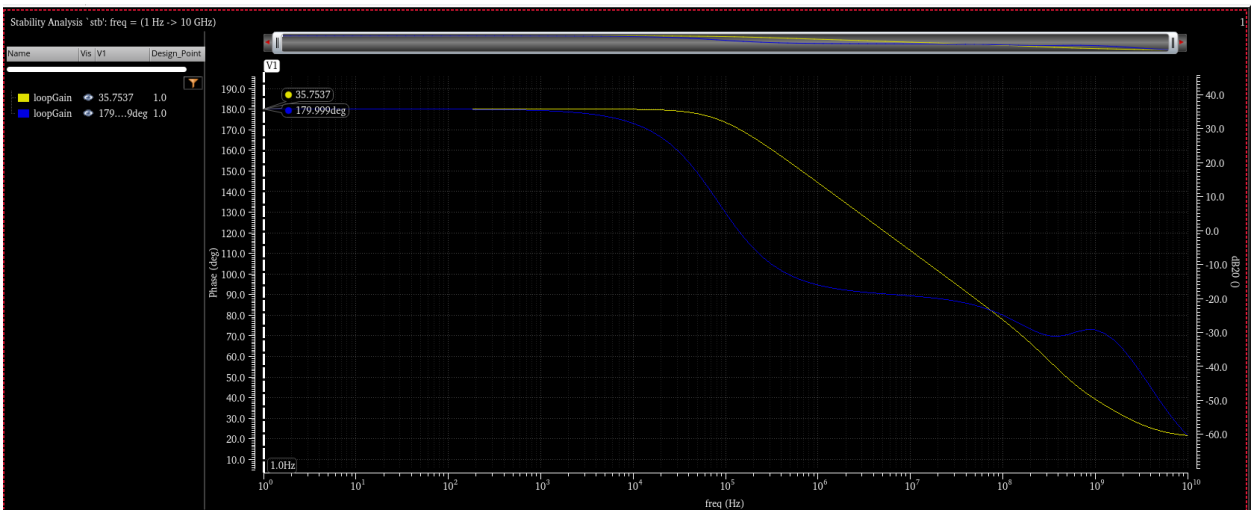
1.2 CALCULATE THE MISMATCH IN ID AND GM.

$$ID = \frac{9.897 - 9.555}{9.555} = 0.0357 = 3.57\%$$

$$gm = \frac{160.3 - 156.6}{156.6} = 0.023 = 2.36\%$$

2 LOOP GAIN:

2.1 PLOT LOOP GAIN IN DB AND PHASE VS FREQUENCY



2.2 COMPARE DC GAIN AND GBW WITH THOSE OBTAINED FROM OPEN-LOOP SIMULATION. COMMENT

	OPEN-LOOP	LOOP GAIN
DC GAIN	35.73 db	35.75 DB
GBW	5.12M	5.10 M

The dc gain of loop gain is higher than open loop because of mismatch happend, but BW in open-loop is higher so GBW in open-loop is higher than loop gain case but they are approximately equal.

2.3 COMPARE SIMULATION RESULTS WITH HAND CALCULATIONS IN A TABLE

	ANALYTICAL	SIMULATION
DC GAIN	$\beta Aol \; and \; \beta = 1$ =34.5 db (the value we ANALYTICALY calculated above)	35.75 DB
GBW	5.07 M $\beta = 1$ same as Open loop we calculated above	5.10 M