

PART 1: Sizing Chart

- 1 WE WANT TO DESIGN A COMMON SOURCE (CS) AMPLIFIER THAT HAS IDEAL CURRENT SOURCE LOAD WITH THE FOLLOWING PARAMETERS.

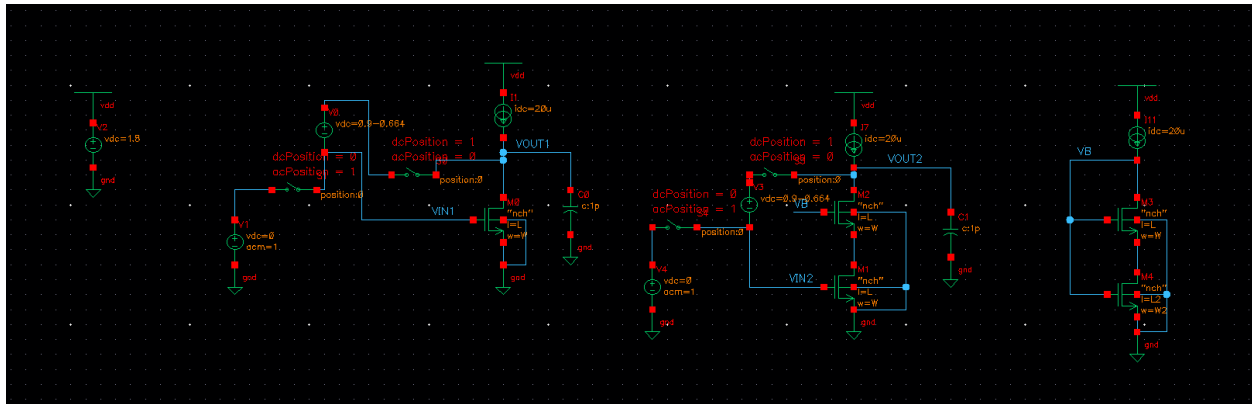
The screenshot shows the 'ADT Sizing Assistant' window. It has a red title bar with standard window controls. Below the title bar are 'Settings' and 'Help' buttons. The 'LUT Settings' section is expanded, showing 'LUTs Directory' as '/home/user01/projects/ex_LUTs/'. Below this are three dropdown menus for 'LUT' (set to 'nch'), 'Corner' (set to 'tt'), and 'Temp (°C)' (set to '27.0'). There is a 'State1' dropdown and a 'Save State' button. A series of input fields follow, each with a dropdown menu: 'ID' (20uw), 'gm/ID' (10), 'gm/gds' (50), 'VDS' (0.9), 'VSB' (0), and 'Stack' (1). Below these are 'Get' and 'Apply' buttons. The 'Y-Expr' field is set to 'gm', with 'Plot', 'Replace', and 'Append' buttons below it. At the bottom is a 'Device Parameters' section containing a table with 13 rows of data.

#	Parameter	Value
1	ID	20u
2	L	240n
3	W	880n
4	VGS	664.6m
5	VDS	900m
6	VSB	0
7	gm/ID	9.832
8	Vstar	203.4m
9	ft	14.72G
10	gm/gds	48.56
11	VA	4.939
12	ID/W	22.73
13	gm/W	223.5

PART 2: Cascode for Gain

OP ANALYSIS

- 1 CREATE A NEW SCHEMATIC. CONSTRUCT THE CIRCUIT SHOWN BELOW.
USE $I_B = 20\mu A$. USE L AND W AS SELECTED IN PART 1 FOR M0, M1, M2, AND M4. USE THE SAME W FOR M3 BUT IT WILL HAVE DIFFERENT L AS WILL BE SHOWN LATER. USE $C_L = 1pF$.



- 2 TO CALCULATE V_B WE NEED TO FIND V_{GS2} BECAUSE $V_B = V_{GS2} + V_{DS1}$. NOTE THAT M2 EXPERIENCES BODY EFFECT, SO ITS V_{GS} WILL BE HIGHER THAN M0 AND M1.

The screenshot shows the 'ADT Sizing Assistant' window. It has a red title bar with a question mark, a lock icon, and a close button. Below the title bar are 'Settings' and 'Help' buttons. The 'LUT Settings' section is expanded, showing the 'LUTs Directory' as '/home/user01/projects/ex_LUTs/'. Below this are dropdown menus for 'LUT' (set to 'nch'), 'Corner' (set to 'tt'), and 'Temp (°C)' (set to '27.0'). There is a 'State1' dropdown and a 'Save State' button. A list of parameters is shown with dropdown menus and text boxes: 'ID' (20u), 'W' (880n), 'L' (240n), 'VDS' (0.45), 'VSB' (0.45), and 'Stack' (1). Below these are 'Get' and 'Apply' buttons. The 'Y-Expr' is set to 'VGS'. At the bottom are 'Plot', 'Replace', and 'Append' buttons. The 'Device Parameters' section at the bottom contains a table with the following data:

#	Parameter	Value
15	gm	197.3u
14	AREA	211.2f
13	gm/W	224.2
12	ID/W	22.73
11	VA	3.733
10	gm/gds	36.83
9	rT	14.73G
8	Vstar	202.7m
7	gm/ID	9.866
6	VSB	450m
5	VDS	450m
4	VGS	776.1m
3	W	880n
2	L	240n
1	ID	20u

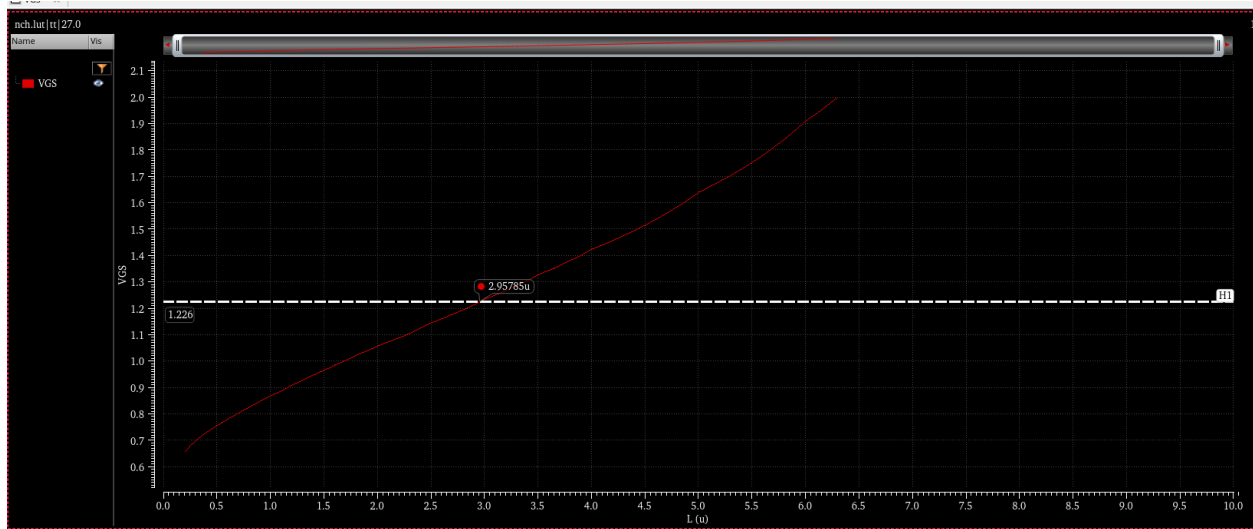
3 **M3** AND **M4** ARE USED TO GENERATE THE CASCODE BIAS VOLTAGE. NOTE THAT **M4** IS ALWAYS IN SATURATION AND **M3** IS ALWAYS IN TRIODE (WHY?). WE NEED TO FIND THE L OF **M3**, SO WE SET A SWEEP FOR **M3** AS SHOWN BELOW

M4 (**M3** in my schematic) is always in saturation as it diode connected, if we assumed that **M3**(**M4** in my schematic) is working in saturation we will find that $v_{ds} = 0V$ as whole V_D drops on the upper saturated transistor, so the down one would be in triode.

The screenshot shows the 'ADT Sizing Assistant' window. It has a red title bar with a question mark icon. Below the title bar are 'Settings' and 'Help' buttons. The 'LUT Settings' section is expanded, showing a directory path '/home/user01/projects/ex_LUTs/'. Below this are fields for 'LUT' (nch), 'Corner' (tt), and 'Temp (°C)' (27.0), each with a dropdown arrow. There is a 'State1' dropdown and a 'Save State' button. Below these are input fields for 'ID' (20u), 'W' (880n), 'L' (empty), 'VDS' (0.45), and 'VSB' (0), each with a dropdown arrow. There is a 'Stack' field with the value '1', a 'Get' button, and an 'Apply' button. Below these is a 'Y-Expr' field with the value 'VGS'. At the bottom are 'Plot', 'Replace', and 'Append' buttons. The 'Device Parameters' section at the bottom contains a table with columns '#', 'Parameter', and 'Value'.

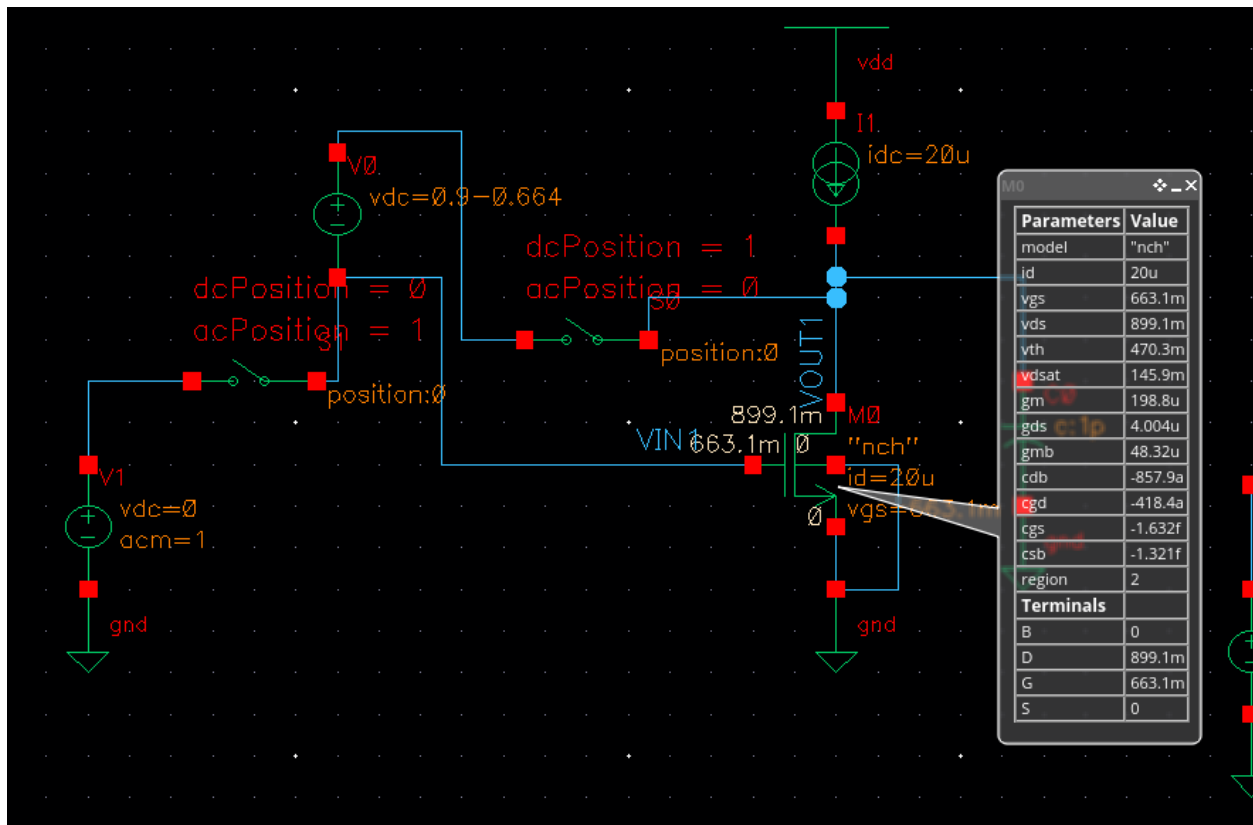
#	Parameter	Value
15	gm	Double click to plot
14	AREA	Double click to plot
13	gm/W	Double click to plot
12	ID/W	Double click to plot
11	VA	Double click to plot
10	gm/gds	Double click to plot
9	rt	Double click to plot
8	Vstar	Double click to plot
7	gm/ID	Double click to plot
6	VSB	Double click to plot
5	VDS	Double click to plot
4	VGS	Double click to plot
3	W	Double click to plot
2	L	Double click to plot
1	ID	Double click to plot

$$V_{GS} + V_{DS} = 0.776 + 0.45 = 1.226$$

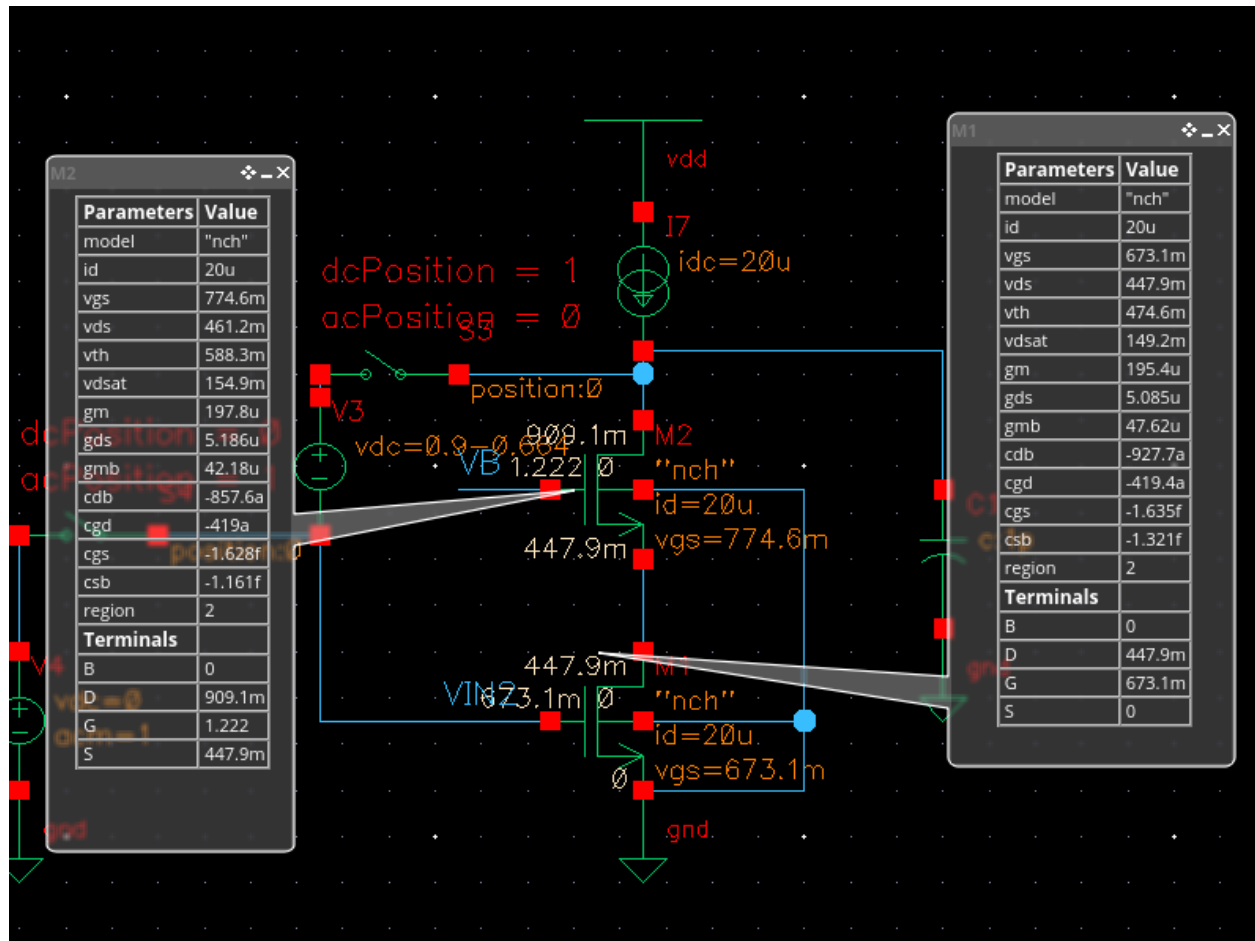


4 SIMULATE THE DC OP POINT OF THE ABOVE CS AND CASCODE AMPLIFIERS.

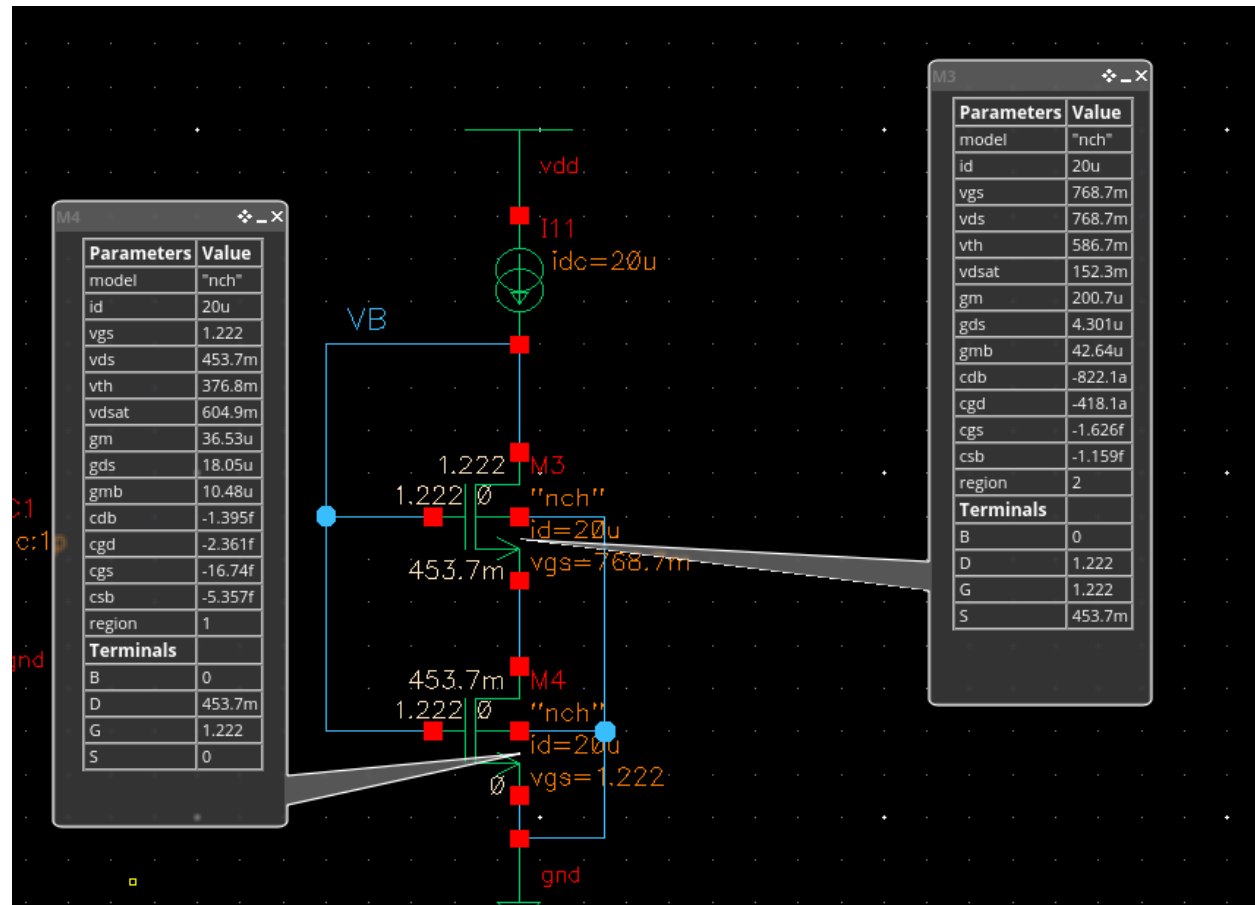
M0:



M1&M2:



M3&M4:



5 CHECK THAT ALL TRANSISTORS OPERATE IN SATURATION.

see vdd...

Cadence Hint: The "region" meaning is as follows: (0 cut-off, 1 triode, 2 sat, 3 subth, and 4 breakdown).

All Transistors are in saturation except m4(m3 in doctor schematic) is in triode.

m0 : vds=899.1m vdsat=145.9m

m1 : vds=447.9m vdsat=149.2m

m2 : vds=461.2m vdsat=154.9m

m3 : vds=768.7m vdsat=152.3m

$v_{ds} > v_{dsat}$ so they are in saturation

m4 : $v_{ds}=453.7m$ $v_{dsat}=604.9m$

$v_{ds} < v_{dsat}$ so it is in triode

explanation : M3 is in saturation because it is diode connected,
 $V_{GS}(m3)=V_{GD}(m4)$, and since $V_{GS}(m3) = V_{TH}+V_{ov}$, then $V_{GD}(m4)>V_{TH}$ then M4
is always in triode

6 DO ALL TRANSISTORS HAVE THE SAME V_{TH} ? WHY?

No, they don't have the same threshold voltage, because of body effect as they don't have the same V_{SB} .

7 WHAT IS THE RELATION (\ll , $<$, $=$, $>$, \gg) BETWEEN g_m AND g_{ds} ?

$g_m \gg g_{ds}$ only in saturation transistors

in M4 only, just $g_m > g_{ds}$

8 WHAT IS THE RELATION (\ll , $<$, $=$, $>$, \gg) BETWEEN g_m AND g_{mb} ?

$g_m > g_{mb}$

9 WHAT IS THE RELATION (\ll , $<$, $=$, $>$, \gg) BETWEEN C_{gs} AND C_{gd} ?

$C_{gs} > C_{gd}$

10 WHAT IS THE RELATION (\ll , $<$, $=$, $>$, \gg) BETWEEN C_{sb} AND C_{db} ?

$C_{sb} > C_{db}$

WE TOOK ABSOLUTE VALUES

AC ANALYSIS

- 1 CREATE A NEW SIMULATION CONFIGURATION. PERFORM AC ANALYSIS (1HZ:10GHZ, LOGARITHMIC, 10POINTS/DECADE) TO SIMULATE GAIN AND BANDWIDTH.

Choosing Analyses - ADE L (7)

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

Start Stop

☐ Center-Span

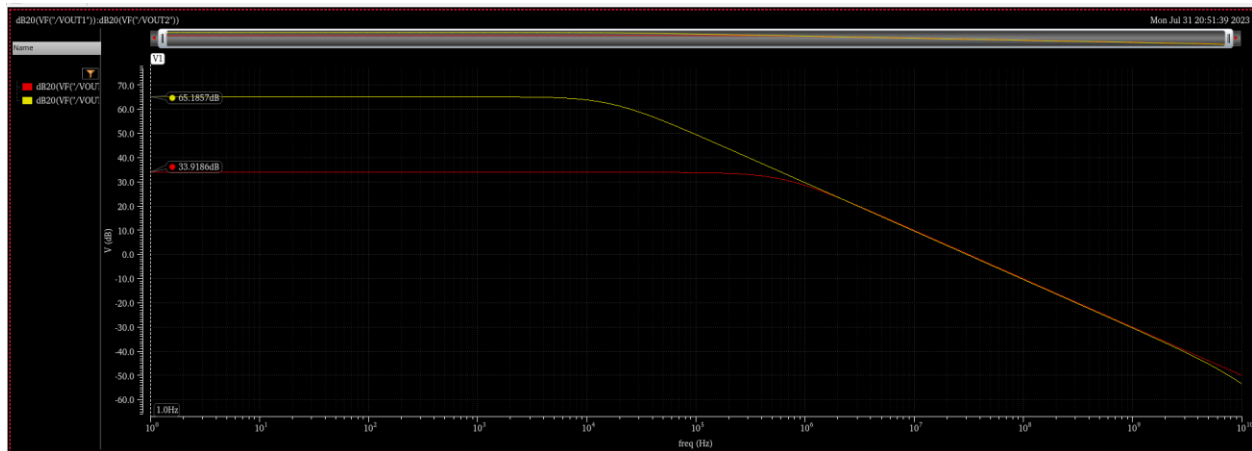
Sweep Type

Logarithmic ☒ Points Per Decade ☐ Number of Steps

Add Specific Points ☐

2 USE CALCULATOR TO CREATE EXPRESSIONS FOR CIRCUIT PARAMETERS (DC GAIN, BW, GBW, AND UGF) AND EXPORT THEM TO ADEXL.

Name	Type	Details	Value	Plot	Save	Spec
	expr	dB20(VF"/VOUT1")		<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	ymax(dB20(VF"/VOUT1"))	33.92	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	ymax(mag(VF"/VOUT1"))	49.65	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	bandwidth(VF"/VOUT1") 3 "low")	635.1K	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	gainBwProd(VF"/VOUT1")	31.62M	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	dB20(VF"/VOUT2")		<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	ymax(dB20(VF"/VOUT2"))	65.19	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	ymax(mag(VF"/VOUT2"))	1.817K	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	bandwidth(VF"/VOUT2") 3 "low")	16.75K	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	gainBwProd(VF"/VOUT2")	30.5M	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	unityGainFreq(VF"/VOUT1")	31.6M	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	unityGainFreq(VF"/VOUT2")	30.63M	<input checked="" type="checkbox"/>	<input type="checkbox"/>	



Cascode:

Cascode

$$|A_v| = g_{m1} r_{o2} (1 + (g_{m2} + g_{mb2}) r_{o1})$$

$$= \frac{295,4 \mu}{5,286 \mu} \left(1 + \frac{(297,8 \mu + 42,28 \mu) \times 2}{5,085 \mu} \right)$$

$$= 2778,2$$

E Salam

Subject: موضوع الدرس

Date: التاريخ

$$W_{mi} = \frac{1}{(19F + 857.69 + 1199) \left(\frac{197.8 + 42.79}{5,196 + 5,083} \right)}$$

$$= 110 K$$

$$BW = \frac{110K}{2\pi} \approx 17.5 K Hz$$

$$UGF = A_o BW = 31.13 M$$

Analytically in cs and cascode cases we can consider $GBW = UGF$

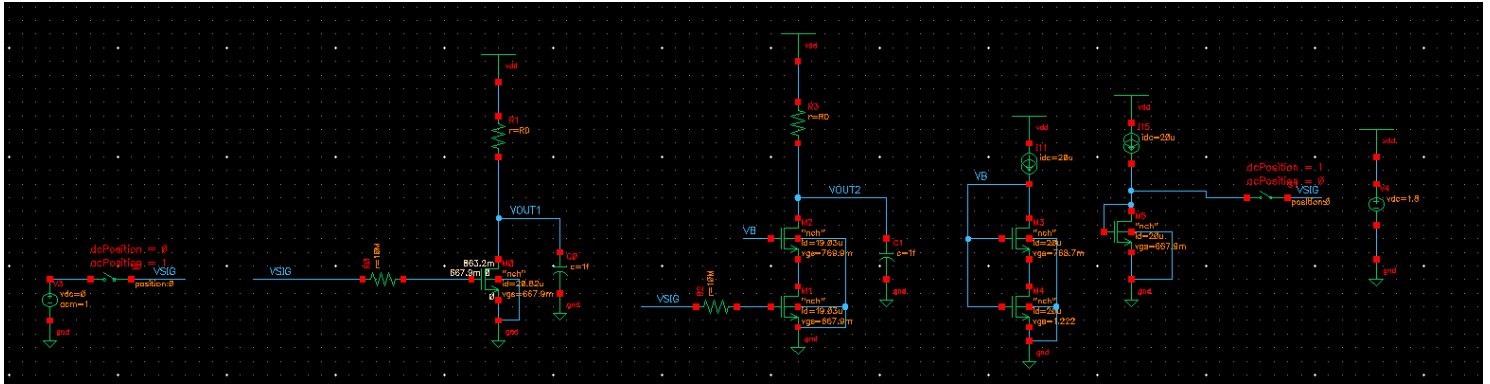
4 REPORT A TABLE COMPARING THE DC GAIN, BW, UGF, AND GBW OF BOTH CIRCUITS FROM SIMULATION AND HAND ANALYSIS.

	Simulation		hand analysis	
	CS	Cascode	CS	Cascode
DC GAIN	49.65	1.817k	49.7	1.78k
BW	635.1k	16.75k	636.6k	17.5k
GBW	31.62M	30.5M	31.6M	31.13M
UGF	31.6M	30.63M	31.6M	31.13M

5 COMMENT ON THE RESULTS.

Dc gain in Cascode is much bigger than the gain in CS as it boosts R_{out} (G_m isn't boosted), and if we compared the hand analysis with the simulation results, we will see they are almost the same, and the increase in R_{out} causes the output pole to be the dominant pole and decreases the bandwidth, While keeping GBW almost unchanged because it is not dependent on R_{out} in cascode for gain.

- 1 CREATE A NEW SCHEMATIC. COPY THE OLD SCHEMATIC INSTANCES TO THE NEW ONE. MAKE THE FOLLOWING MODIFICATIONS

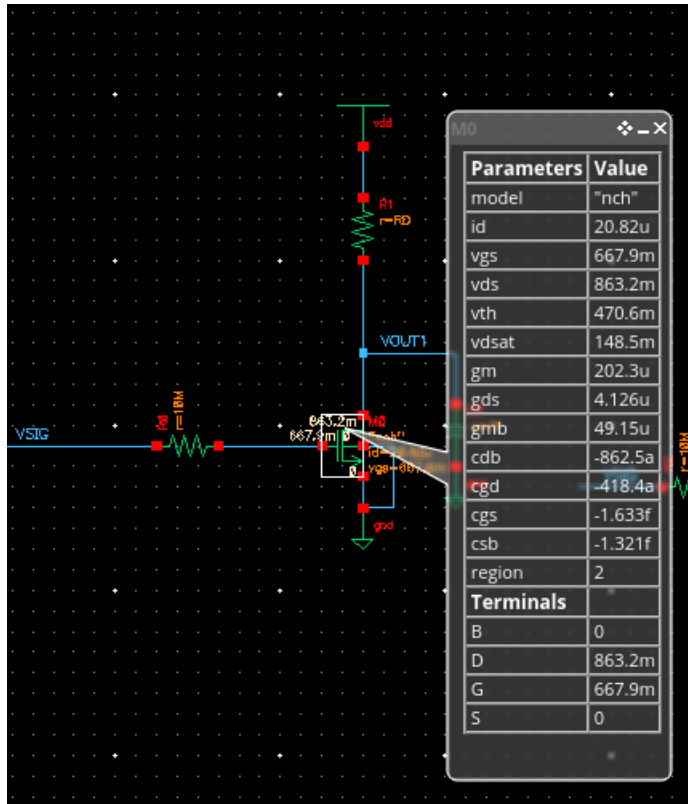


- 2 CALCULATE RD ANALYTICALLY SUCH THAT THE VOLTAGE DROP ON IT IS $\approx VDD/2$

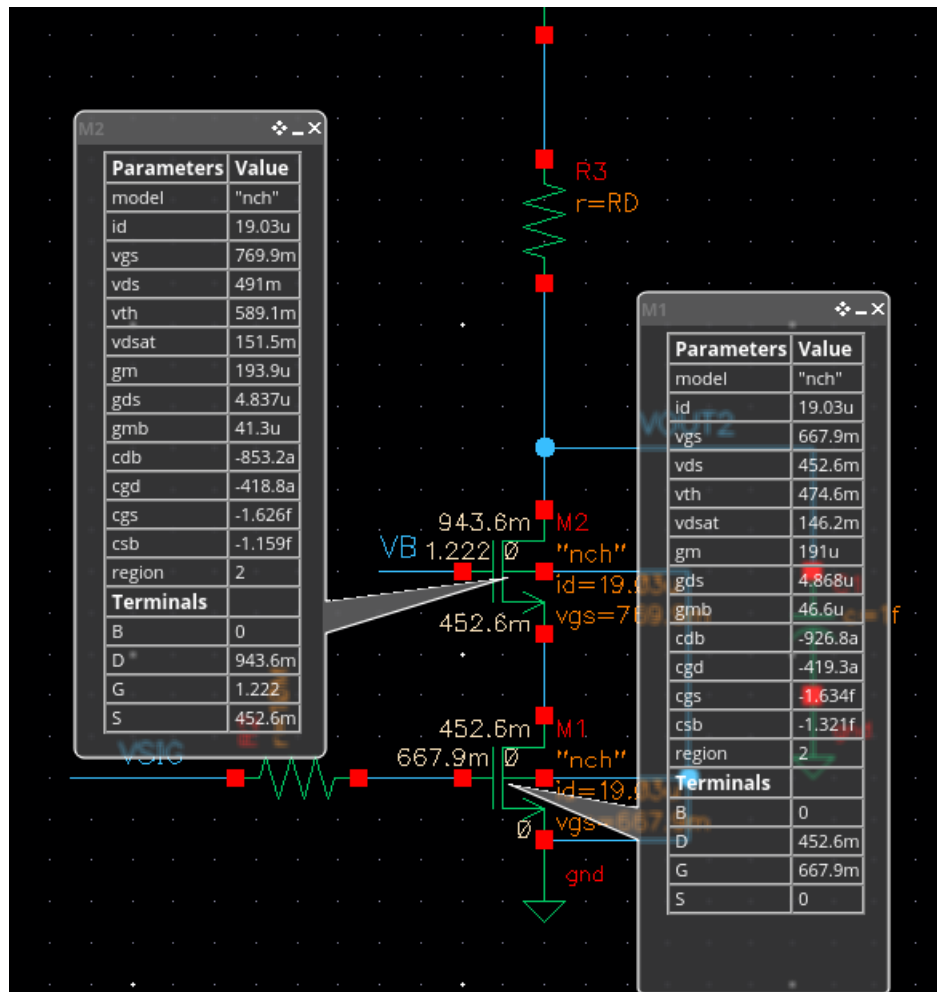
$$RD = \frac{1.8/2}{20\mu A} = 45k \text{ ohm}$$

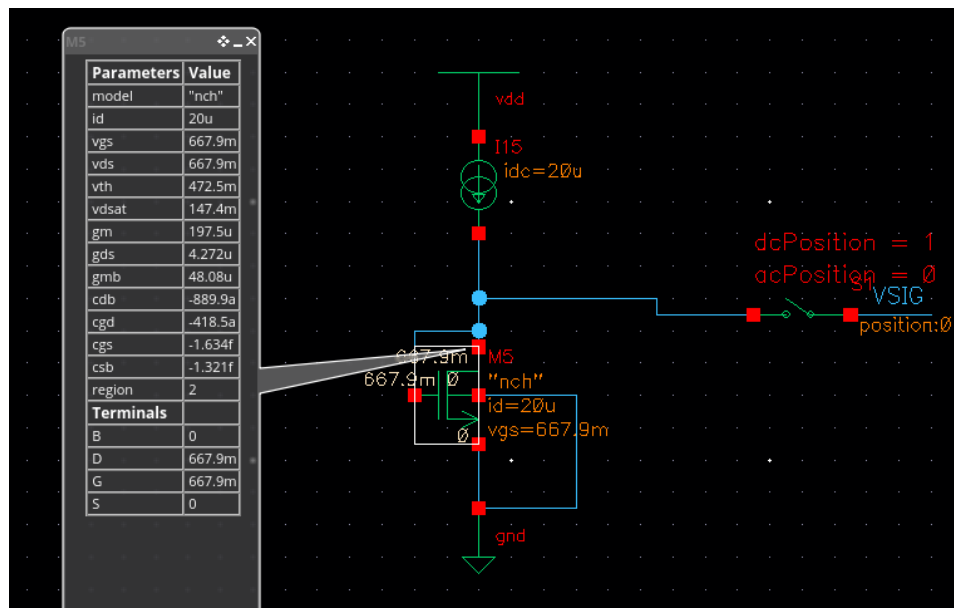
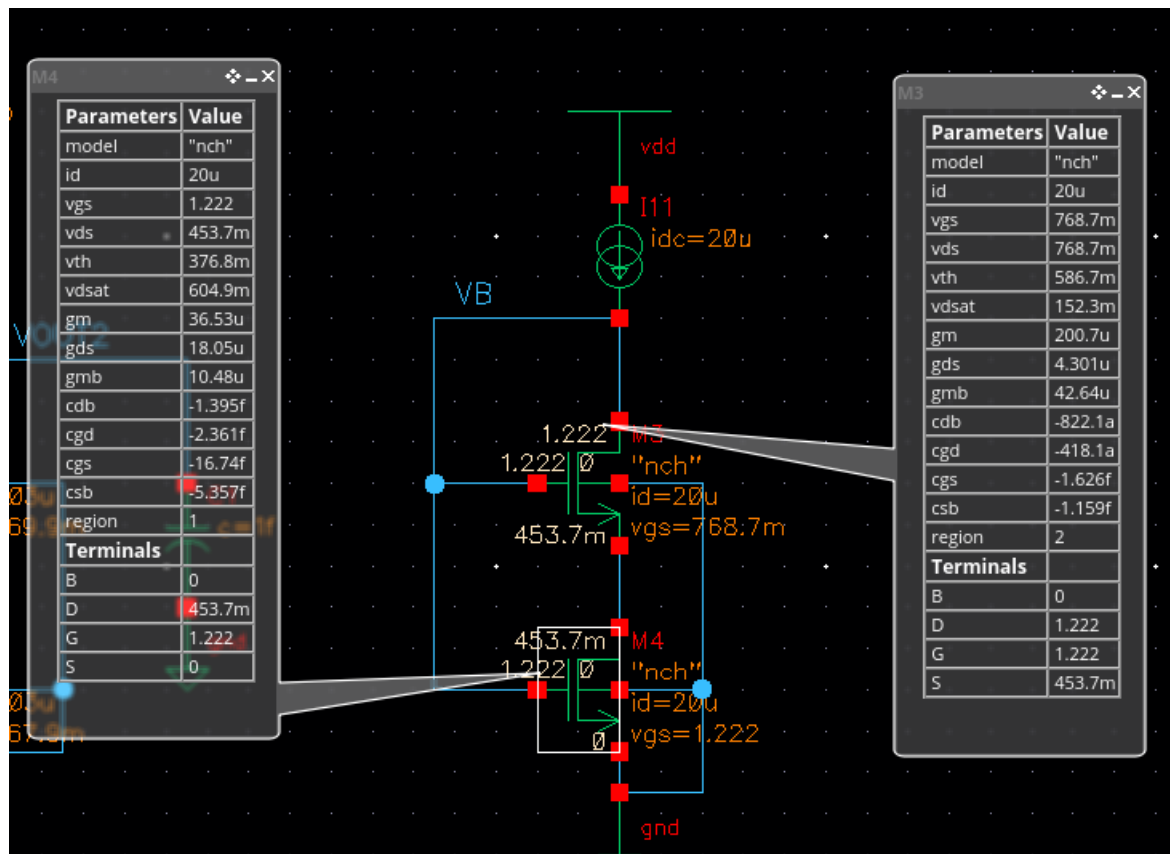
3 SIMULATE THE DC OP OF THE NEW CS AND CASCODE AMPLIFIERS

M0 (new cs)



M1 & M2 cascode amplifiers :





4 CHECK THAT ALL TRANSISTORS OPERATE IN SATURATION.

All transistors are in saturation as they have $v_{ds} > v_{dsat}$. But only M4 (bottom transistor in VB circuit) is in triode.

AC Analysis

1 PERFORM AC ANALYSIS (1HZ:10GHZ, LOGARITHMIC, 10POINTS/DECADE) TO SIMULATE GAIN AND BANDWIDTH.

The screenshot shows the 'Choosing Analyses -- ADE Assembler' dialog box. The 'Analysis' section has radio buttons for various analysis types: tran, dc, ac (selected), 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, and hbxf. The 'AC Analysis' section is expanded, showing 'Sweep Variable' with radio buttons for Frequency (selected), Design Variable, Temperature, Component Parameter, Model Parameter, and None. The 'Sweep Range' section has radio buttons for Start-Stop (selected) and Center-Span, with 'Start' set to 1 and 'Stop' set to 10G. The 'Sweep Type' section has a dropdown menu set to 'Logarithmic' and radio buttons for Points Per Decade (selected) and Number of Steps, with 'Points Per Decade' set to 10. There are checkboxes for 'Add Specific Points' and 'Add Points By File', both of which are unchecked. The 'Specialized Analyses' section has a dropdown menu set to 'None'. At the bottom, there is an 'Enabled' checkbox which is checked, an 'Options...' button, and a row of buttons: 'OK' (highlighted in red), 'Cancel', 'Defaults', 'Apply', and 'Help'.

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

☐ hbsp ☐ hbxf

AC Analysis

Sweep Variable

☒ Frequency

☐ Design Variable

☐ Temperature

☐ Component Parameter

☐ Model Parameter

☐ None

Sweep Range

☒ Start-Stop Start 1 Stop 10G

☐ Center-Span

Sweep Type

Logarithmic

☒ Points Per Decade 10

☐ Number of Steps

Add Specific Points ☐

Add Points By File ☐

Specialized Analyses

None

Enabled ☒

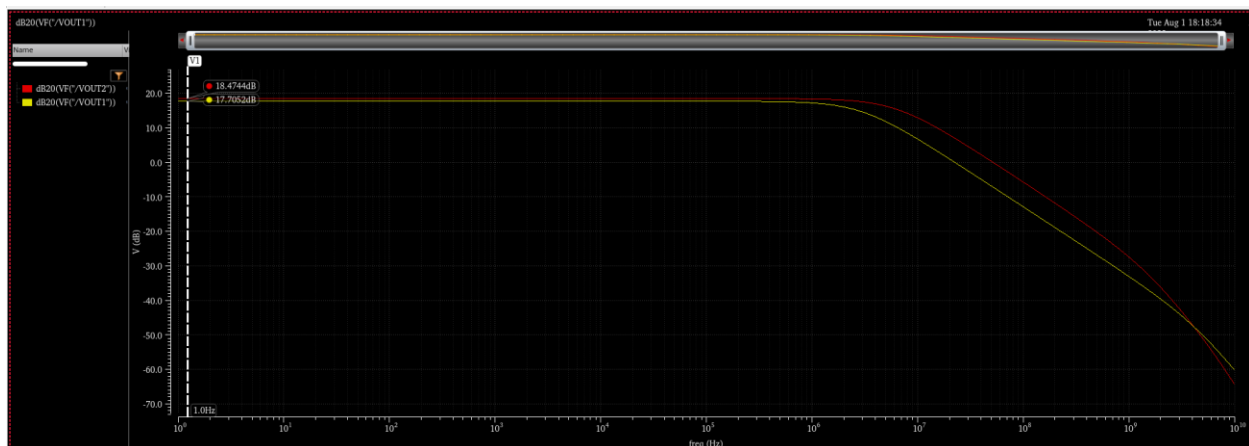
Options...

OK Cancel Defaults Apply Help

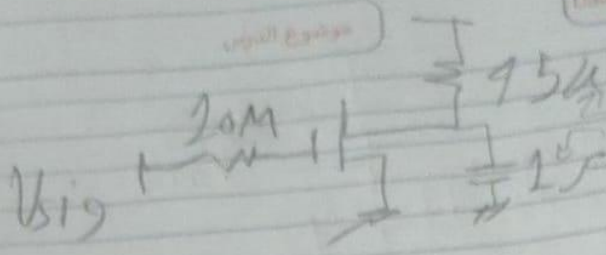
2 USE CALCULATOR TO CREATE EXPRESSIONS FOR CIRCUIT PARAMETERS (DC GAIN, BW, GBW, AND UGF) AND EXPORT THEM TO ADEXL AS IN PART 2

Test	Output	Nominal	Spec	Weight	Pass/Fail
Filter	Filter	Filter	Filter	Filter	Filter
lab3_lab3part3_1	dB20(VF("/VOUT1"))				
lab3_lab3part3_1	ymax(dB20(VF("/VOUT1")))	17.71			
lab3_lab3part3_1	ymax(mag(VF("/VOUT1")))	7.678			
lab3_lab3part3_1	bandwidth(VF("/VOUT1") 3 "low")	2.962M			
lab3_lab3part3_1	gainBwProd(VF("/VOUT1"))	22.79M			
lab3_lab3part3_1	dB20(VF("/VOUT2"))				
lab3_lab3part3_1	ymax(dB20(VF("/VOUT2")))	18.47			
lab3_lab3part3_1	ymax(mag(VF("/VOUT2")))	8.389			
lab3_lab3part3_1	bandwidth(VF("/VOUT2") 3 "low")	6.222M			
lab3_lab3part3_1	gainBwProd(VF("/VOUT2"))	52.32M			
lab3_lab3part3_1	unityGainFreq(VF("/VOUT1"))	22.83M			
lab3_lab3part3_1	unityGainFreq(VF("/VOUT2"))	52.21M			

3 REPORT THE BODE PLOT (MAGNITUDE) OF CS AND CASCODE APPENDED ON THE SAME PLOT.



4 CALCULATE DC GAIN, BW, AND GBW OF BOTH CIRCUIT



$$|A_{ol}| = g_m (R_D \parallel V_o) = g_m \frac{R_D V_o}{R_D + V_o}$$

$$= 7,67$$

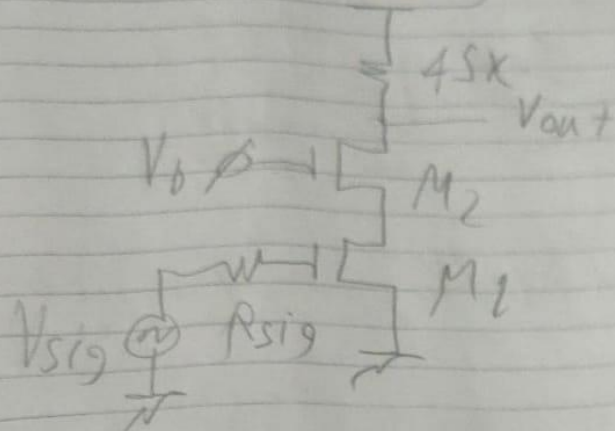
$BW = C_{L \downarrow} \text{ and } R_{out \downarrow}, R_{sig \uparrow}$

$$W_H = \frac{1}{R_{sig} (C_{gs} + C_{gd} (1 + A_{ol}))}$$

$$= 19,02 \text{ M}$$

$$BW = 3,02 \text{ MHz}$$

$$GBW = A_{ol} f_H = 23,16 \text{ M}$$



$$A_0 = g_{m2} \left[V_{o2} \left[(g_{m2} + g_{mb2}) V_{o2} / R_D \right] \right]$$

$$\approx g_{m2} R_D = 8,6$$

Bandwidth $R_D \downarrow R_{sig} \uparrow$ i/p Pole dominates

$$\omega = \frac{1}{R_{sig}(C_{gs1} + 2C_{gd1})} = 40,4 \text{ M}$$

$$f_H \approx 6,3 \text{ M}$$

$$GBW = A_0 f_H = 54,2 \text{ M}$$

- 5 REPORT A TABLE COMPARING THE DC GAIN, BW, UGF, AND GBW OF BOTH CIRCUITS FROM SIMULATION AND HAND ANALYSIS. COMMENT ON THE RESULTS.

	Simulation		hand analysis	
	CS	Cascode	CS	Cascode
DC GAIN	7.678	8.389	7.67	8.6
BW	2.962M	6.22M	3.02M	6.3M
GBW	22.79M	52.32M	23.16M	54.2M
UGF	22.83M	52.21M	23.16M	54.2M

When R_{sig} is increased and R_{out} is decreased, we notice that In CS the gain is decreased, but the bandwidth is increased compared to using an ideal load(I_{DC}), because this made the input pole dominant, In cascode the gain is decreased as the output impedance is decreased and input is increased this made the input pole the dominant pole. But the input pole is larger than the common source input pole, which means that the bandwidth was extended, this is due to the Miller effect being decreased, And the gain bandwidth product is no longer the same as in CS but it is higher.