Part 1: sizing chart

•First get value of RD $=\frac{V_{RD}}{I_D}$ $\quad V_{RD} = {V_{DD}}/{2}$ =0.9v $\quad I_D = 100\mu A$

Then RD=6kΩ

• we can get gain is given by:

$$|Av| \approx gmRD = \frac{2 * I_D * RD}{V_{OV}} = \frac{2 * V_{RD}}{V_{OV}}$$

But for real mosfet $V_{OV} \neq \frac{2*I_D}{gm}$ we define new expression $V^* = \frac{2*I_D}{gm}$

•For a square-law device, V^*= V_{OV},however for a real MOSFET they are not equal. The actual gain is now given by $\quad |Av| \approx \frac{2*V_{RD}}{V^*}$

•we have $|Av| = 6$ then $V^* = \frac{2*V_{RD}}{A_v}$ $=\frac{2*0.9}{8}$ =225mV, which we make the operating point voltage of real MOSFET overdrive voltage $V_Q^* = 225mV$.

• And we assume that channel length value will be L=2um, to avoid short channel effects.

•By using sizing assistant, we have this parameter:

L=$2\mu m$

I_D =$100\mu A$

$V^* = 225mV \qquad gm = \frac{2*I_D}{V^*} = \frac{2*100\mu}{225M} = 888.88\mu S$

$V_{DS} = 0.9V \qquad V_{SB} = 0\ V$

After using sizing assistant, the value of other parameters generated

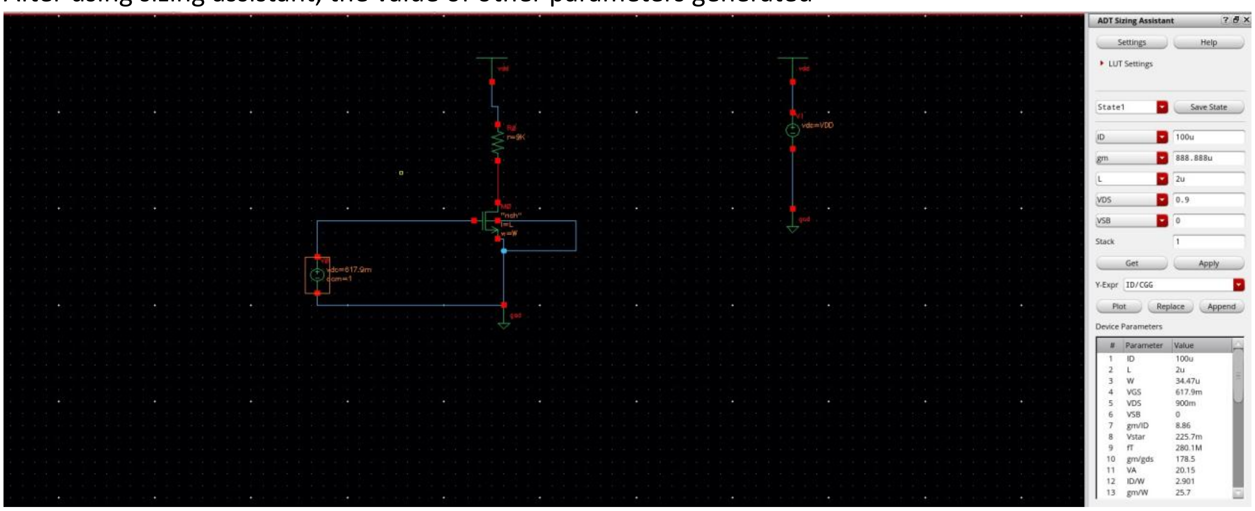


Figure 1 results of sizing assistant

By applying AC analysis, we get this result and use parameters of sizing assistant.

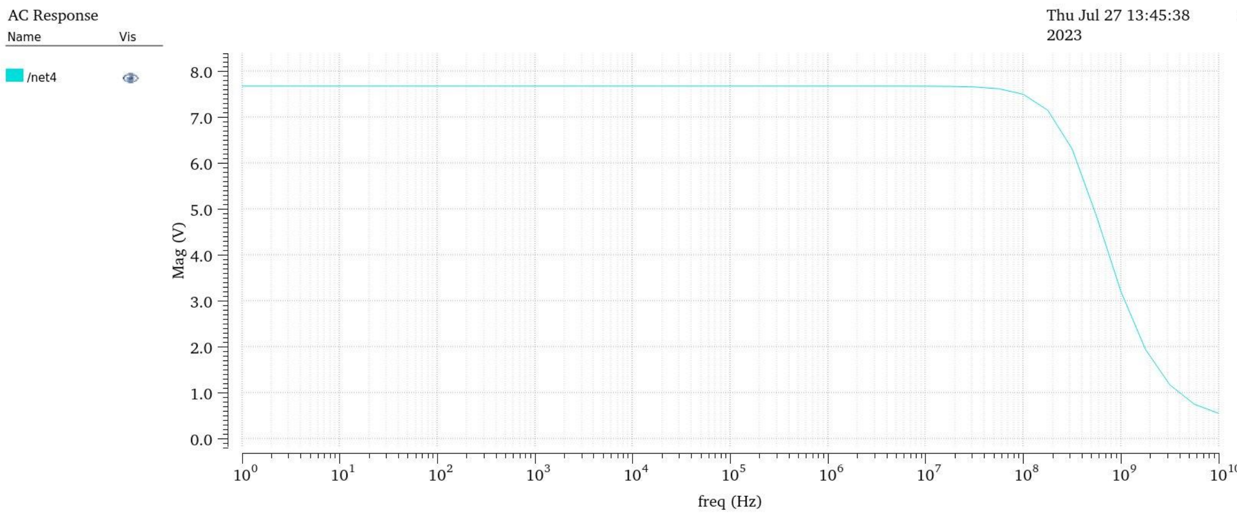


Figure 2 AC analysis to get value of the gain

As shown on figure DC gain =7.6 , I want the gain to be 8 by increasing the value of gm gain will be increased

$$A_v = -gm * (r_0||RD)$$

By increasing gm to 950μS and decreasing V^* to 211.6mV

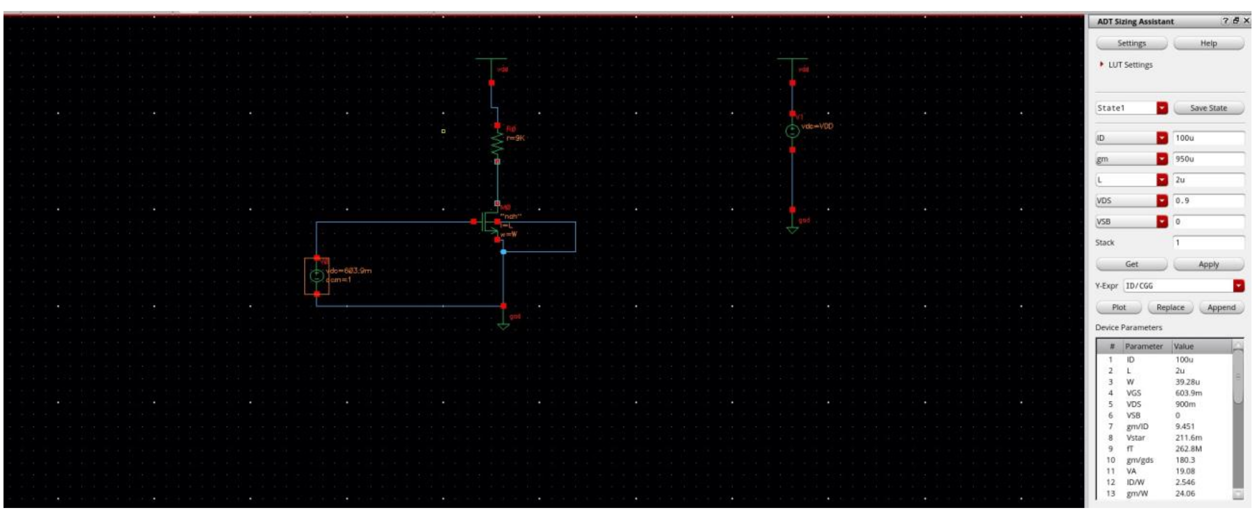


Figure 3 sizing assistant results gm=950u results

When I used the parameters W=39.28μm and $V_{GS} = 603.9mV$ DC gain will equal 8 as shown below.

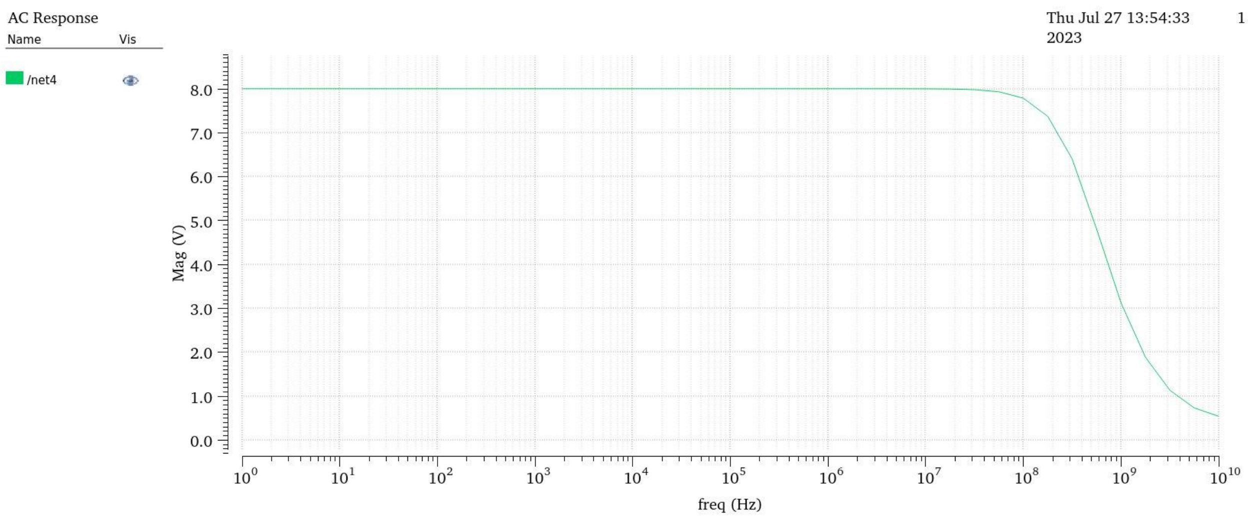


Figure 4 AC analysis to get gain.

Get DC operating point.

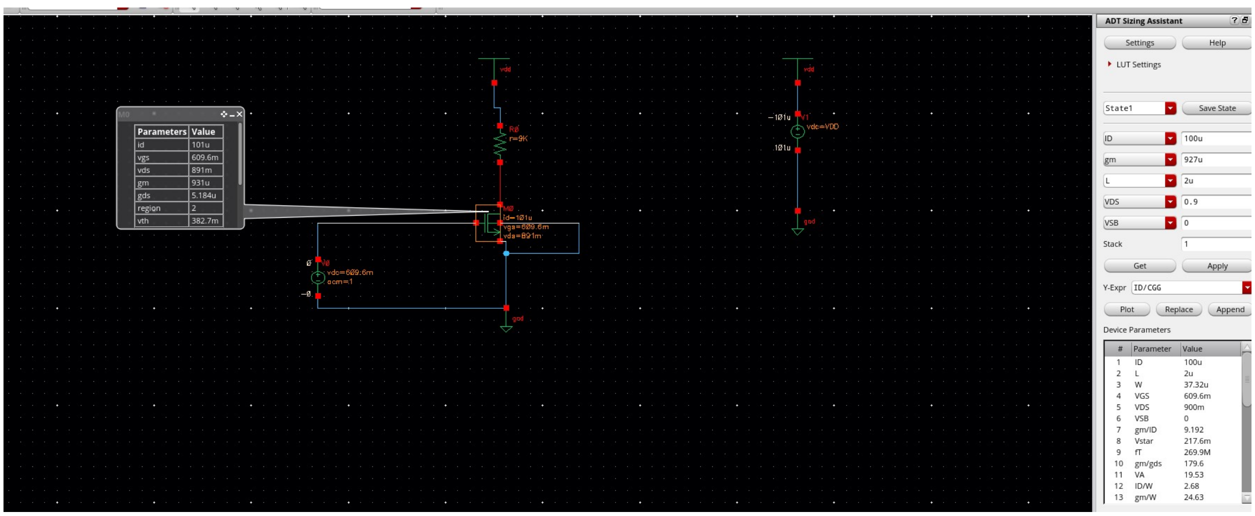


Figure 5 DC operating point

gm	$931\mu S$
gds	$5.84\mu S$
Vth	382.7mV

$$A_v = -gm * (r_0||RD) = -931\mu * (9K\ ||\frac{1}{5.184\mu}) = -8.005$$

Part 2:CS Amplifier

1. OP and AC Analysis

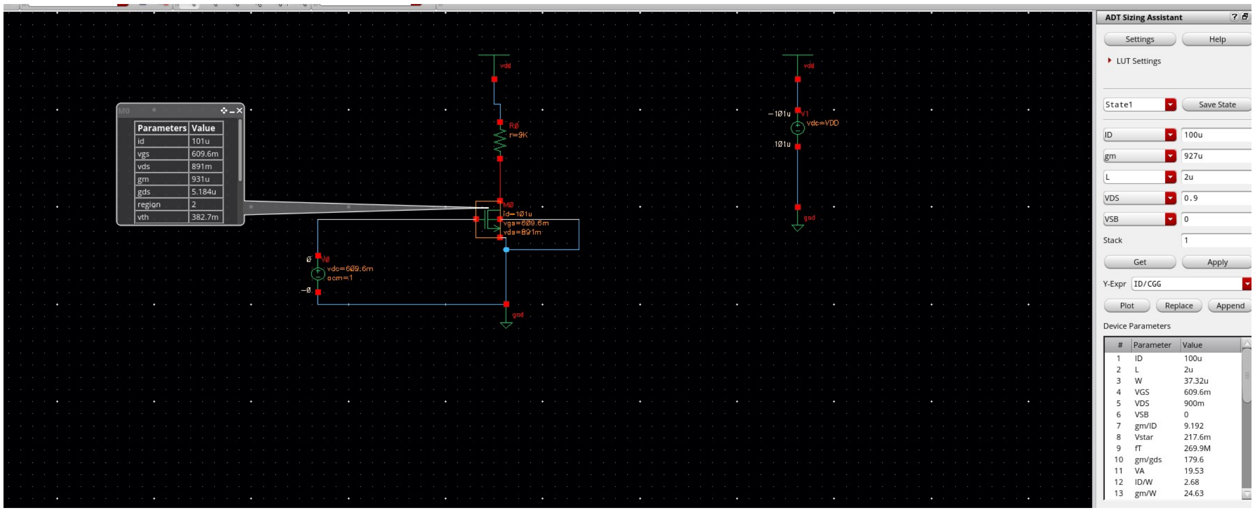


Figure 6 operating point in cs amplifier

Parameter	CS amplifier
I_D	101µA
gm	931μS
gds	5.184µS
r_o	192.901KΩ
V_{GSQ}	609.6mV

• From these results we found that there is a great agreement between our results in part 1 and CS amplifier simulation part and region of MOSFET equal 2 which mean that MOSFET is in saturation region.

3) $r_o = 192.901$KΩ>>>RD=9KΩ

$R_{OUT} = r_o||RD \cong$ 8.6KΩ which is very close to RD we can neglect value of r_o.

•if we minimum channel length the value of $r_o$will decrease following the relation $r_o = \frac{1}{\lambda I_{DS}}$

and λ α $\frac{1}{L}$ $\therefore r_o \; \alpha \; L$. the error will not remain the same, and ro will be smaller and the error will be larger.

• Intrinsic gain of MOSFET will be:

$$A_v = -gm * r_0 = -950\mu * 192.901K = -183.255$$

• Amplifier gain analytically:

$$A_v = -gm * (r_0||RD) = -8.005.$$

From these calculations we found that intrinsic gain is greater than amplifier gain

∴ intrinsic gain>>amplifier gain.

•From simulation we can find DC gain:

DC gain =8.005

DC gain in dB =18.07

This values meets specs .

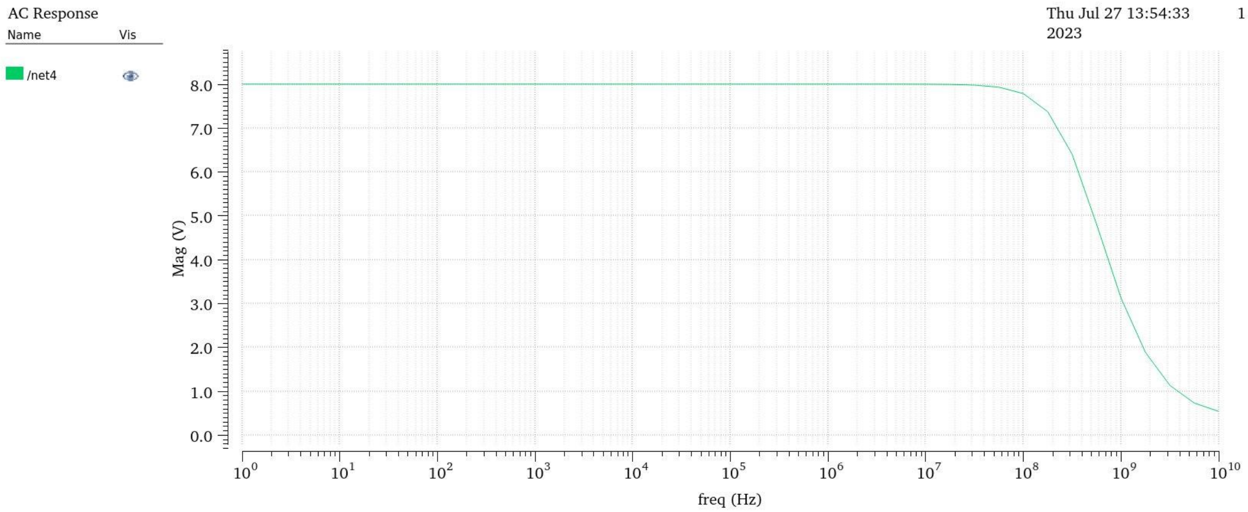


Figure 7 plot gain vs Frequency

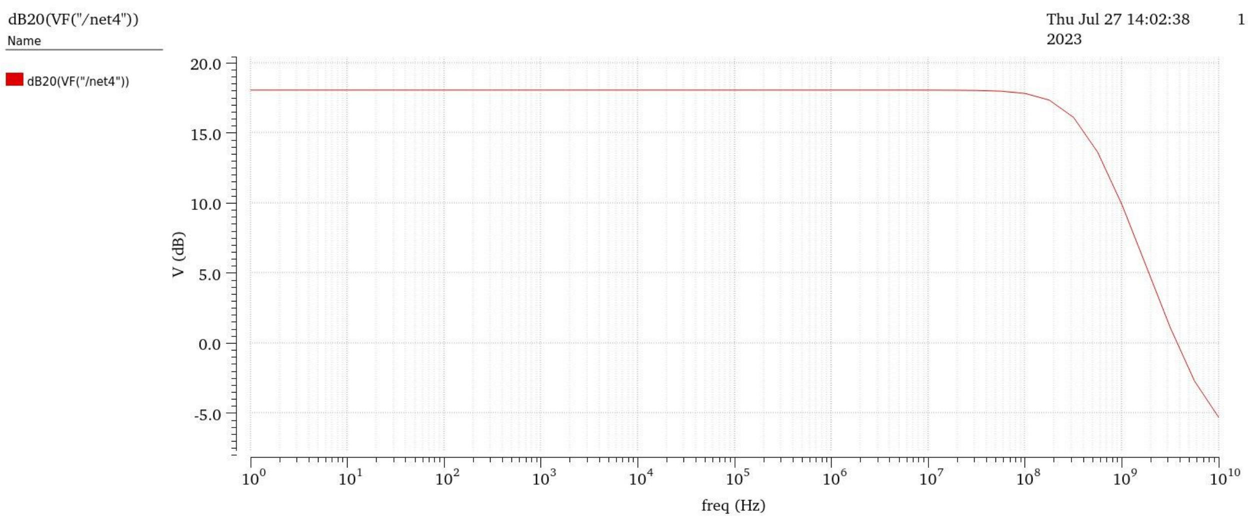
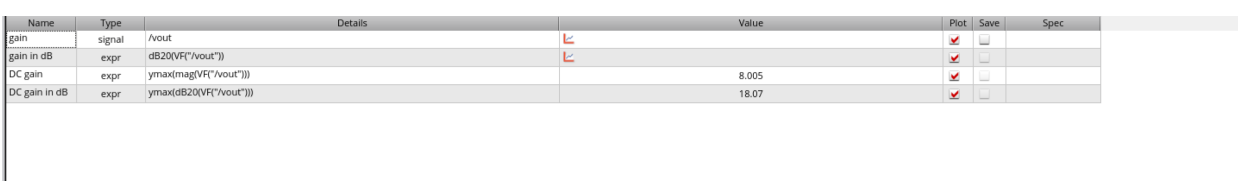


Figure 8 plot gain in dB VS Frequency



Name	Type	Details	Value	Plot	Save	Spec
gain	signal	/vout		✔		
gain in dB	expr	dB20(VF("/vout"))		✔		
DC gain	expr	ymax(mag(VF("/vout")))	8.005	✔		
DC gain in dB	expr	ymax(dB20(VF("/vout")))	18.07	✔		

Figure 9 values of gain from simulator

2. Gain Non-Linearity

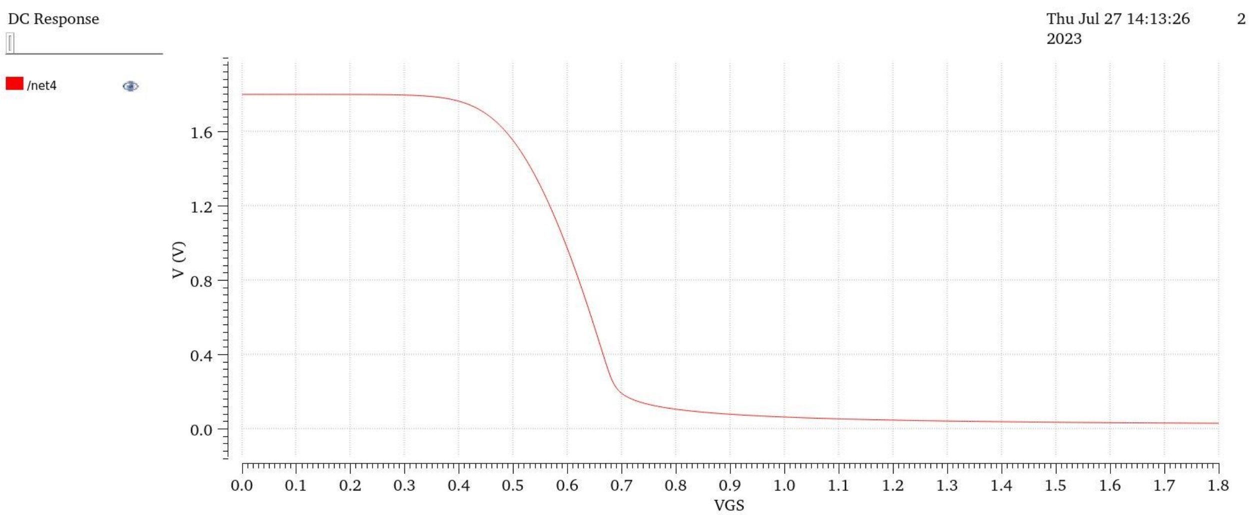


Figure 10 Vout Vs Vin in DC Sweep

• this is a nonlinear relation as V_{OUT} =VDD-IR is which depends on current whose relation depends on region of operation hence Vin and you know I depend on Vin = V_{gs}

ID = (1/2) (W/L) μ$C_{ox}(V_{gs} - V_{th})^2$.

with quadratic relation in saturation that's why it is nonlinear.

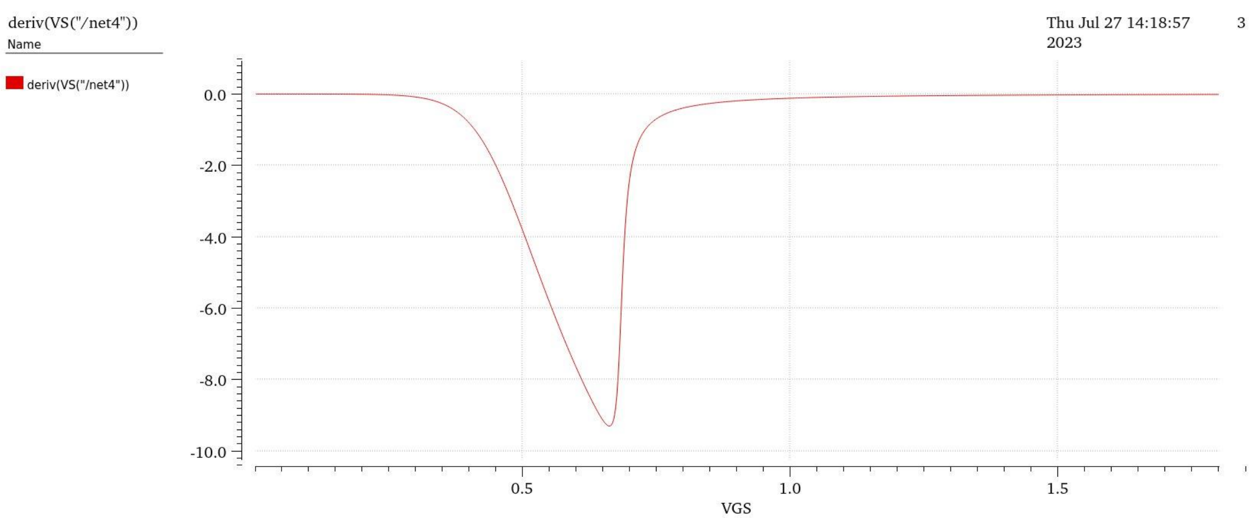


Figure 11 derivative of Vout vs Vin

•The figure shown in Figure indicates that the derivative of V_{OUT} is not a constant value. This is because the relationship between V_{OUT} and V_{in} is not linear, as it depends on the current that depend on which region of operation, is dependent onV_{GS}.

Transient analysis:

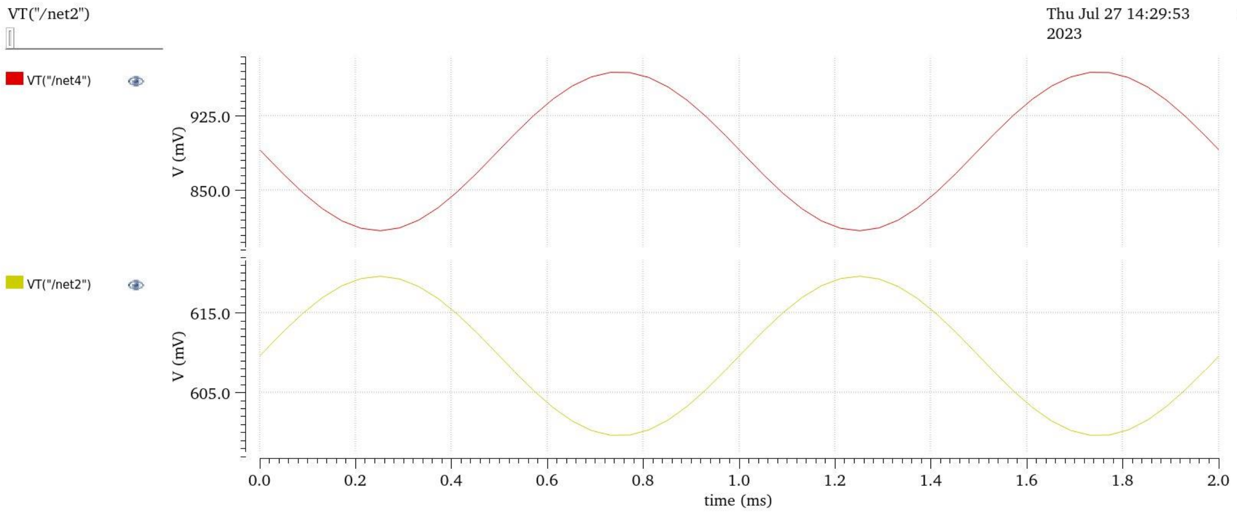


Figure 12 transient anlysis of Vout and Vin

Plot gm in transient analysis

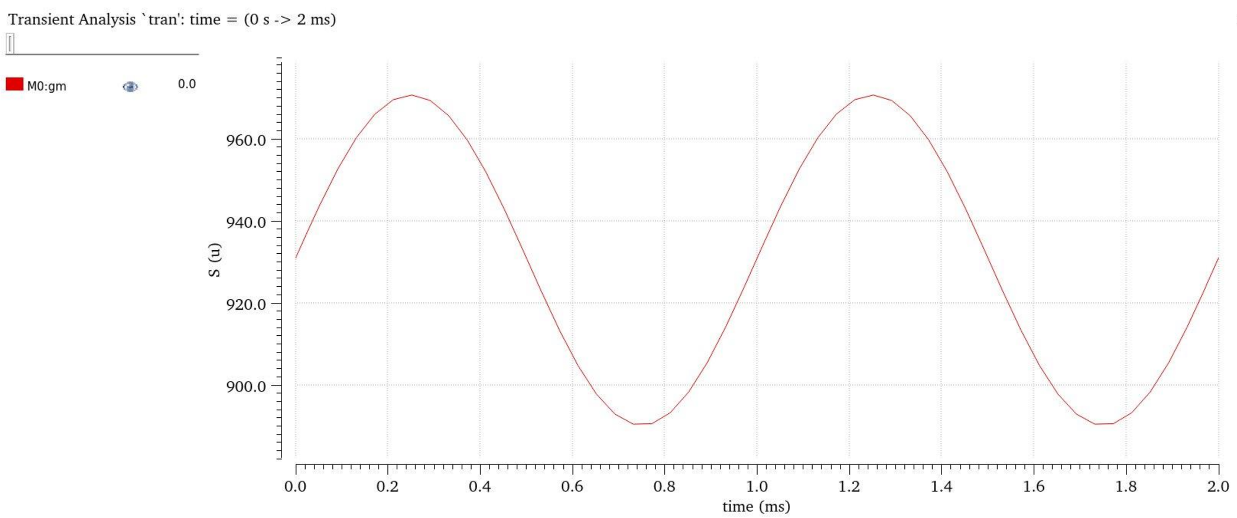


Figure 13 plot gm in transient analysis

5) as shown figure, the variation of gm over time demonstrates that gm is dependent on the input voltage V_{GS}, which in turn is time dependent. Therefore, gm exhibits a strong dependence on the input voltage V_{GS}.

6)Based on the previous analysis, it is evident that our amplifier is a non-linear amplifier due to the non-linear relationship between its input voltage and output voltage. This non-linearity arises from the dependence of the amplifier's gain on gm, which is heavily strongly by the input voltage V_{GS}. As a result, the non-linear dependence of gm on V_{GS} leads to non-linearity in the amplifier's gain.

3. [Optional] Maximum Gain

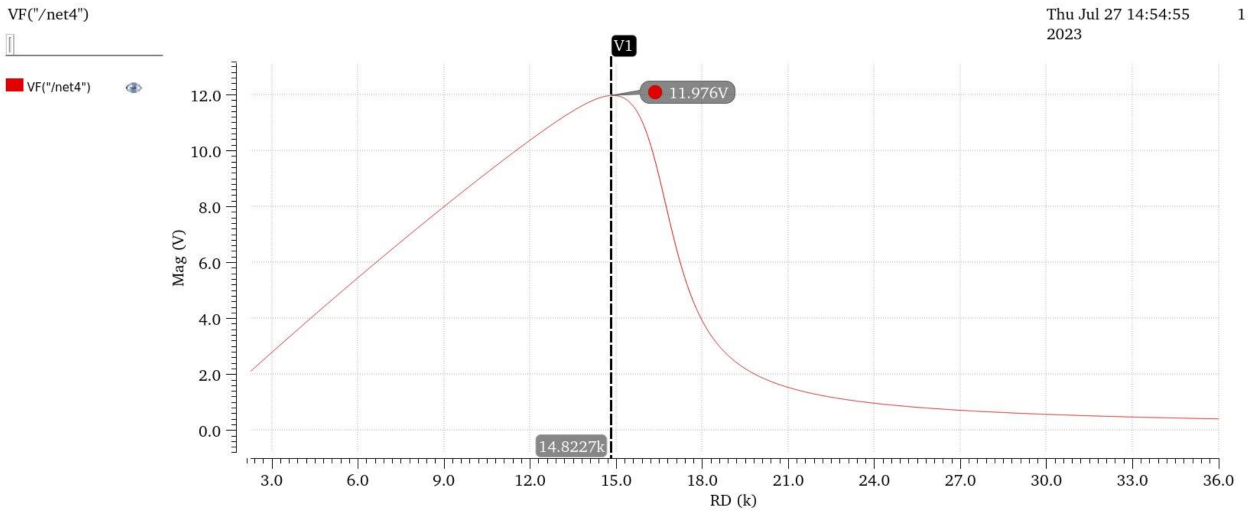


Figure 14 AC anlysis plot Vout vs RD

As shown in the figure the gain increased with RD then decreased at certain point, because I have constant current as RD increases at certain point, I will be entering the triode region then gain will decrease.

From the simulator highest RD =14.8227KΩ this gives you max gain =11.976

Hand analysis:

$A_v = -gm * (r_o||RD)$ =$-gm * \frac{r_o*RD}{r_o+RD}$

I have $I_D = 100\mu A$ and $v^* = 225mV$ then $V_{RD} = 1.8 - 0.225 = 1.575V$

$RD_{max} = 15.75K\Omega$

$A_v = -gm * (r_o||RD)$ =-931$\mu * \frac{192.901K*15.75K}{192.901K+15.75K} = 13.55$

	Simulator	Hand analysis
RD	14.8227KΩ	15.75KΩ
Gain	11.976	13.55

Output signal swing:

$Vout_{max} = VDD = 1.8V$

$Vout_{min} = V_{OV} \cong V^* = 225mV$

I have tried out to get max swing I put sinusoidal input signal =125mv results below

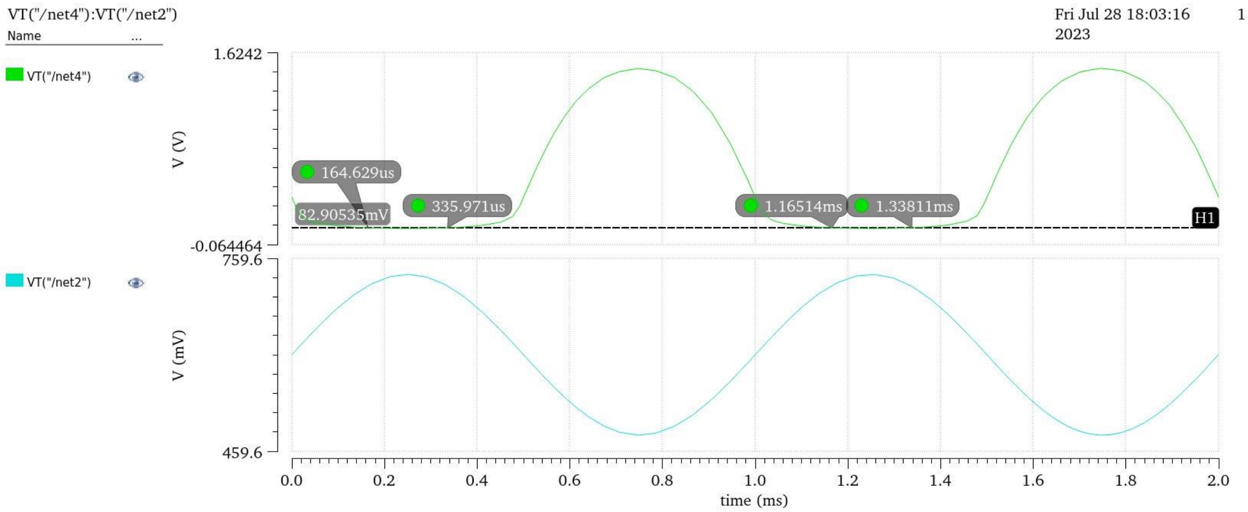


Figure 15 transient analysis at input 125Mv

As shown on above figure I have exceed minimum range (225 mV) the $Vout_{\min\ \_graph} = 82.9mV$

To make it in the range, decrease the input signal, I have tried out with different values of input until get max sinusoidal signal =11.5mV.

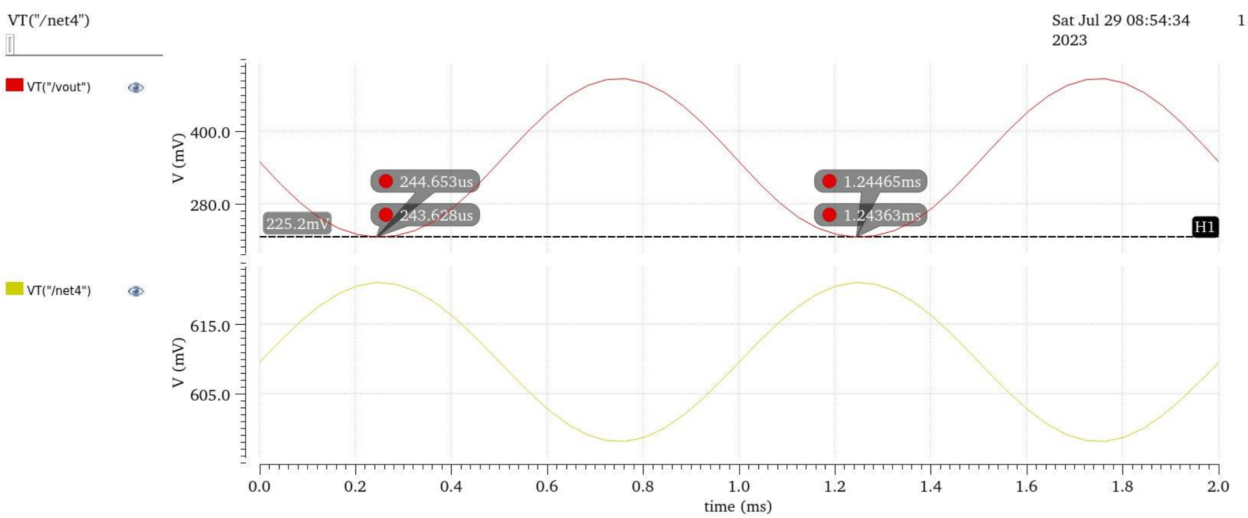


Figure 16 Ttansient analysis at 11.5mV input

. I have get vout to minimum value 225.2mV at input 11.5mV

8)No, Certainly, when scaling down the supply voltage in a power amplifier while keeping the drain current (ID) constant, the value of RD that leads to the edge of saturation will decrease. Consequently, the maximum achievable gain of the amplifier will also decrease. Additionally, the reduced supply voltage will limit the maximum available output voltage swing. As a result, this limitation can have a negative impact on the overall gain of the amplifier.

4. [Optional] Gain Linearization (feedback)

By using sizing assistant with parameters for PMOS Like NMOS of part one

L=2μm $\quad$ I_D =100μA

$gm = 950\mu S \qquad V_{DS} = 0.9V \qquad V_{SB} = 0\ V$

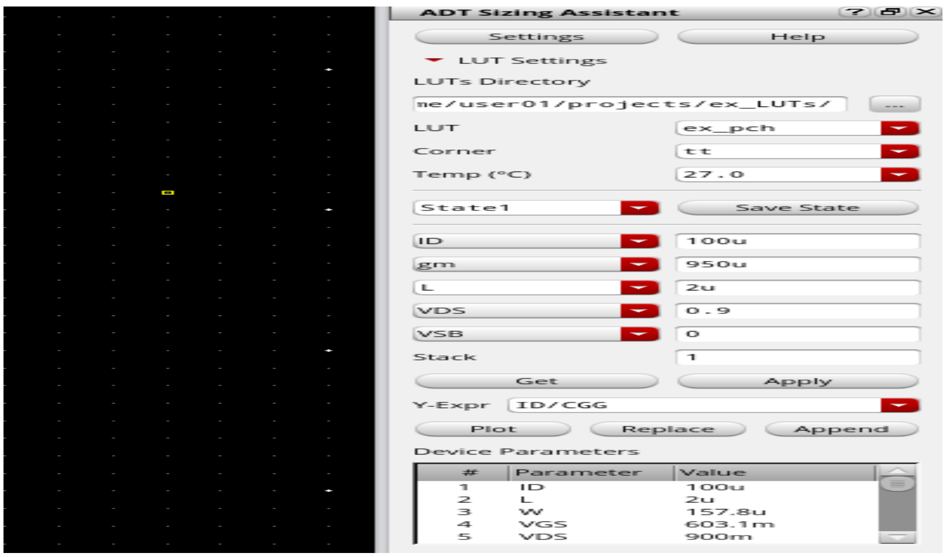


Figure 17 PMOS SIZING

As shown in figure sizing assistant generate W=157.8$\mu m\ and\ V_{GS} = 603.1mV$.

$A_v = \frac{RF}{R_{in}} = 8$ then RF =1MΩ.

7) the two curves cross at 619.355mV which is nearly to V_{GS} for NMOS =619.9mV, because of no current flows through resistor at point $V_{OUY} = V_{IN}$.

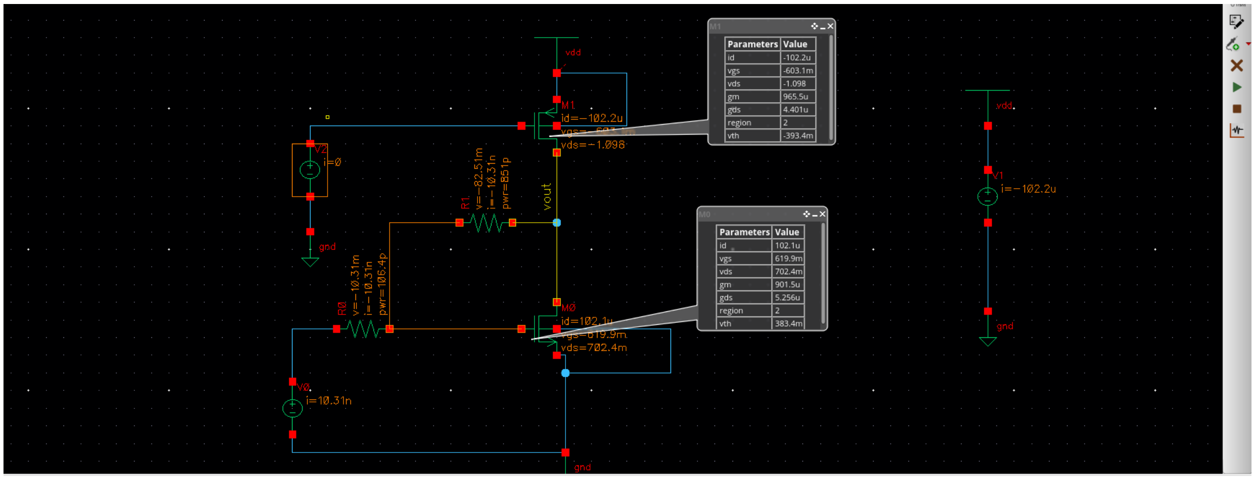


Figure 18 DC operating point

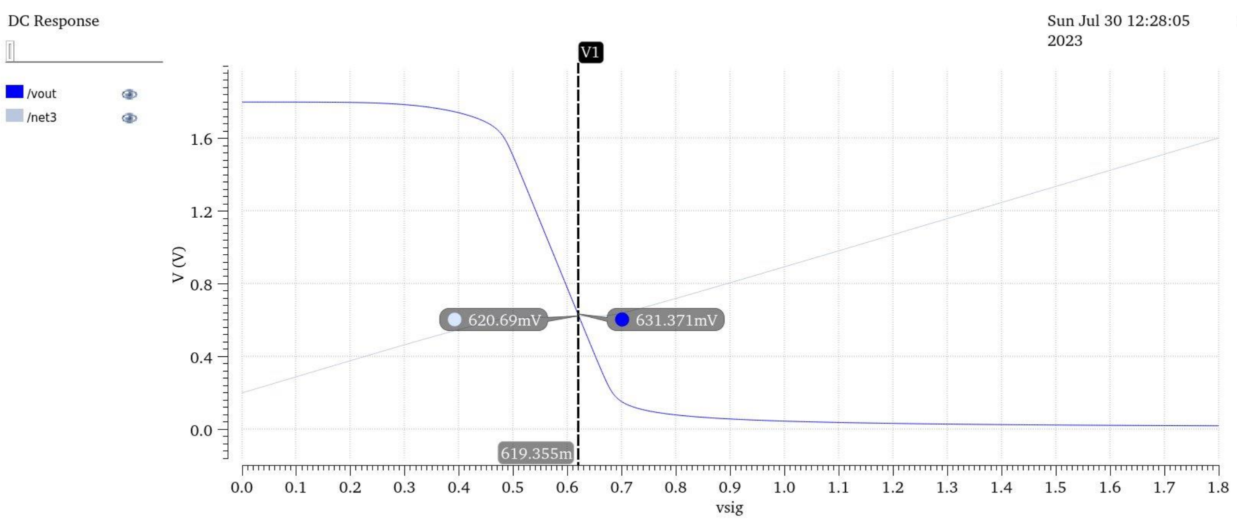


Figure 19 plot vout and vin vs Vsig

8)yes, in saturation region V_{OUT} is linear to V_{sig} due to presence the feedback resistor

Calculate new gain:

$$R_{OUT} = r_{o1}||r_{o2}||(RF + R_S)||\frac{RF+R_S}{gm1*R_S}$$

$$GM = \frac{1-gm1*R_F}{RF+R_S}$$

Gain = GM*R_{OUT}

From relations gain is linear in sat region.

Why gain is linear? Because gm is this region nearly constant thus the gain linear shown in figures below.

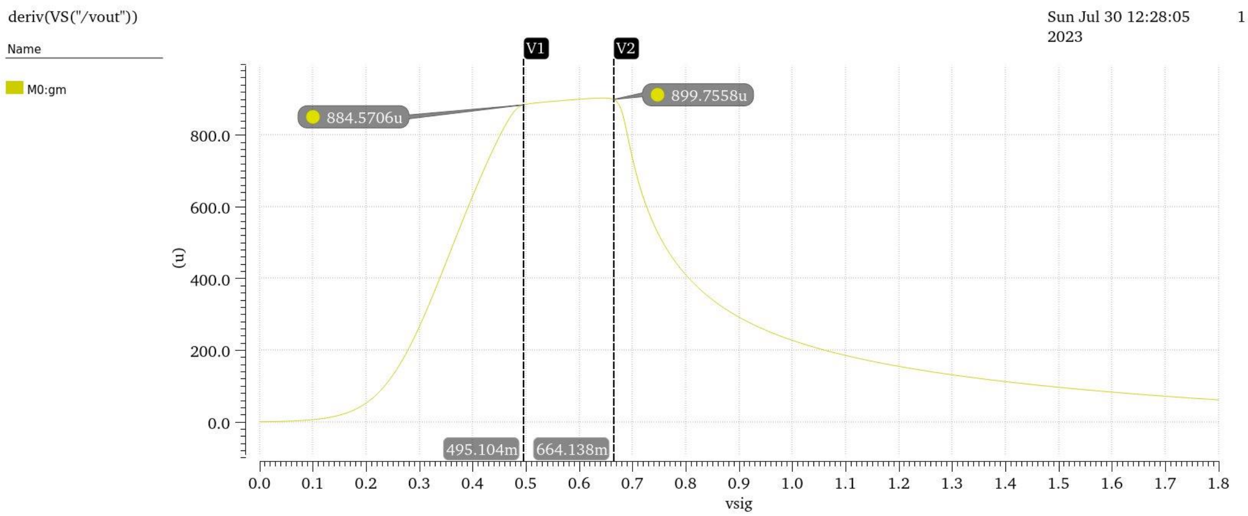


Figure 21 plot gm vs Vsig at sat region

• these two graphs show gm is nearly constant at sat region and gain is linear in sat region.

9)the derivative of vout is constant at saturation region because in this region gain is linear because

Using feedback resistor, gm is constant in sat region, no variations with input swing.

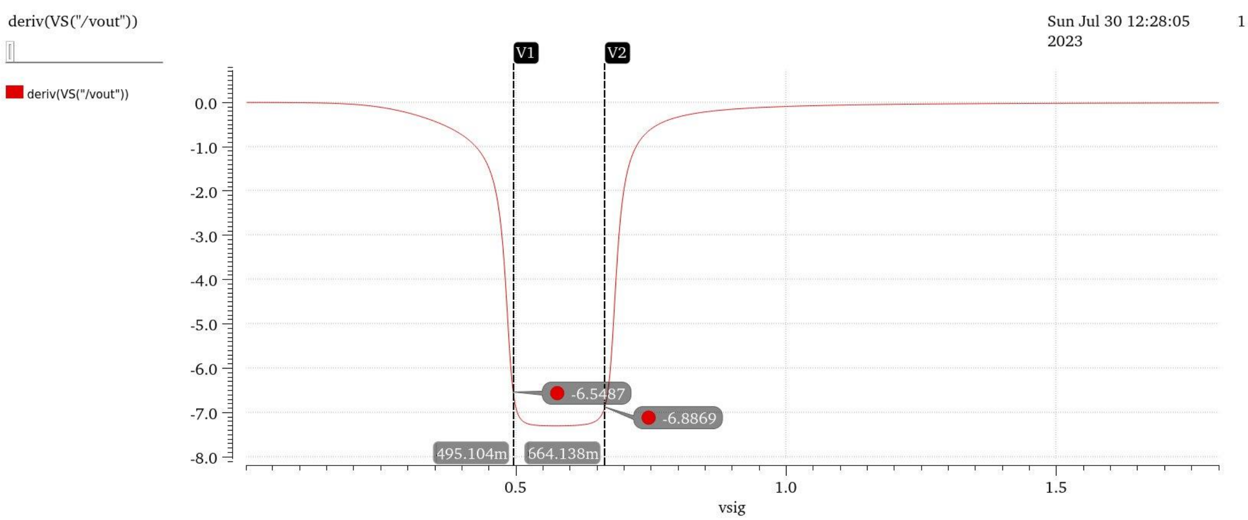


Figure 22 plot dervative of gm vs Vsig and regions

10) from 495.104mV to 664.138mV.

Range=664.138m -495.104m =0.17V

11) $V^* < V_{OUT} < VDD - V^*$ From part one I have used $V^* = 211.6mV$

211.6m< $V_{OUT} < 1.8 - 211.6m.$

DC input Range =$\frac{VDD-2*V^*}{A_v} = \frac{1.8-2*0.211}{8} = 0.172$

	Simulator	Analytical
Range	0.17 V	0.17 V