Part 1: sizing chart

•First get value of RD =$\frac{V_{RD}}{I_D}$ $V_{RD} = {V_{DD}}/{2}$ =0.9v $I_D = 150\mu A$

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 $|Av| \approx \frac{2*V_{RD}}{V^*}$

•we have $|Av| = 6$ then $V^* = \frac{2*V_{RD}}{A_v}$ =$\frac{2*0.9}{6}$ =0.3V, which we make the operating point voltage of real MOSFET overdrive voltage $V_Q^* = 0.3V$.

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

• from LAB01 we can get value of V_{TH} for NMOS

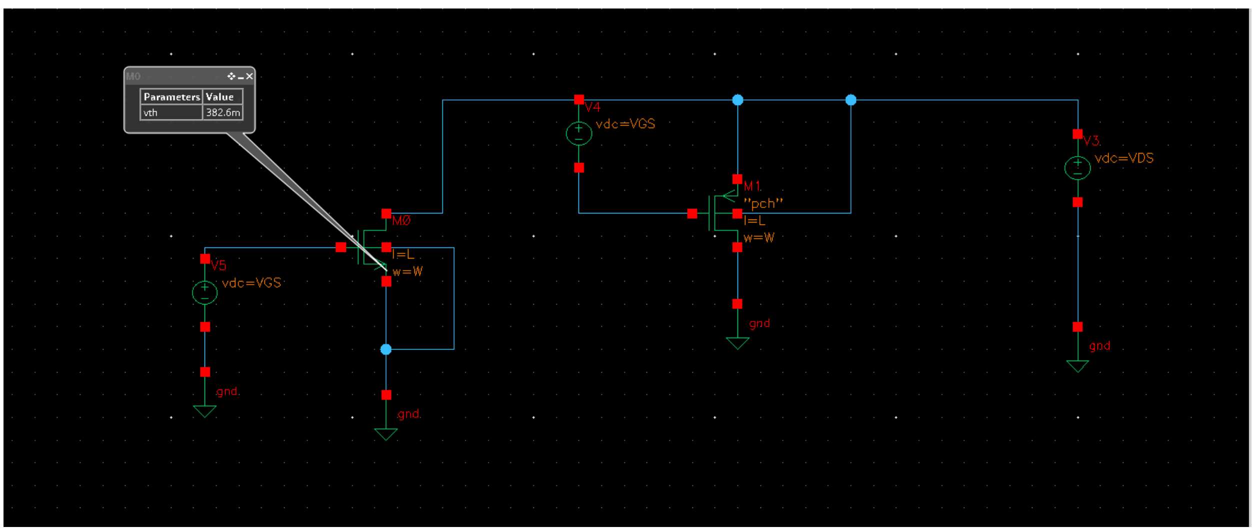

Figure 1 get value of VTH

By making dc analysis simulation we get $V_{TH} = 382.6mV$.

• Sweep V_{GS} from 0 to ≈ V_{TH} + 0.4V 0→ $782.6mV$ with 10mV step. Set V_{DS} = $\frac{V_{DD}}{2} = 0.9$V.

• firstly, assume the width of MOSFET to be W=10um, L=2um.

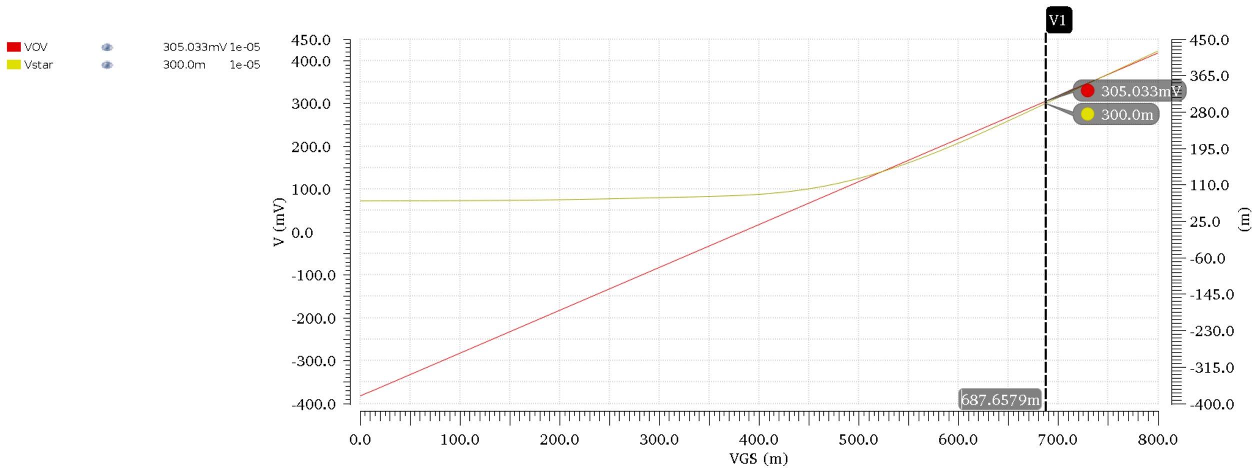

*Figure 2 simulation V*and Vov vs VGS*

- from simulation we found at $V_{GSQ} = 687.6579mV$, $V_{OVQ} = 305.033mV$, $V_Q^* = 300mV$

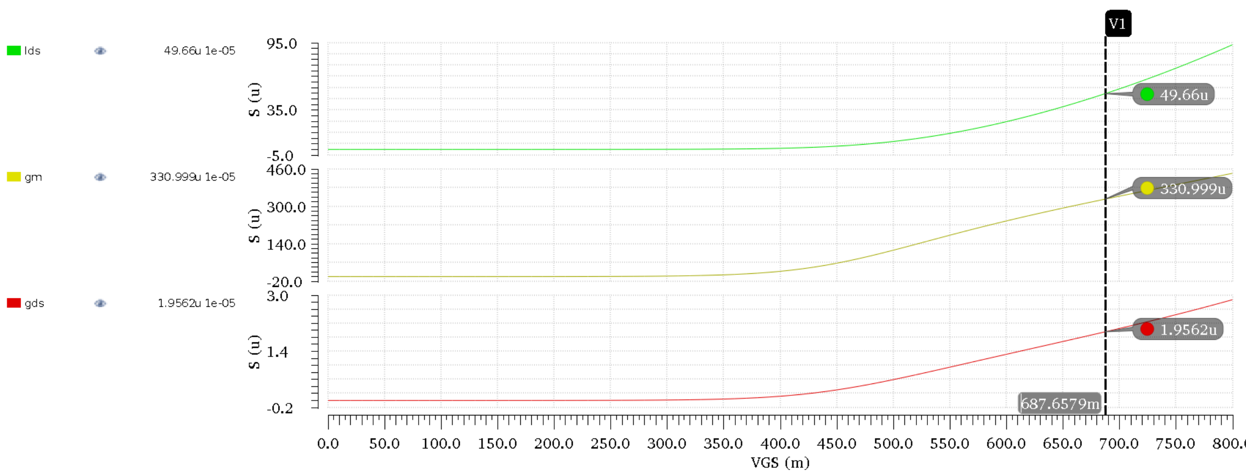

Figure 3 simulation ID&gm and gds VS VGS

- from simulation we found the values in this table at $V_{GS} =$:

Parameter	Simulator value
V_{OVQ}	305.033mV
V_Q^*	300mV
I_{DQ}	49.66μA
gm_Q	330.999μS
gds_Q	1.9562μS

- I want current equal 150μA but at W=10μm $I_{DQ} = 49.66\mu A$

W	I_D
10μm	49.66μA
?	150μA

Then W=$\frac{150\mu * 10\mu}{49.66\mu} = 30.205\mu m$

- get parameters at this W:

$\frac{gm}{gm_Q} = \frac{W}{W_Q}$ $\frac{gm}{330.999\mu} = \frac{30.205}{10}$ $gm = 999.782\mu S$

$\frac{g_{ds}}{gds_Q} = \frac{W}{W_Q}$ $\frac{gds}{1.9562\mu} = \frac{30.205}{10}$ $gds = 5.9087\mu S$

$I_D = 150\mu A$

$r_o = \frac{1}{gds} = 169.241K\Omega$

So common source parameters is:

Parameter	Value
L	2µm
W	30.205µm
V_{GSQ}	687.6579mV
I_D	150μA
RD	6KΩ
gm	999.782μS
gds	5.9087μS
r_o	$169.241K\Omega$

- Gain =gm*(RD||r_o)=5.8.

Part 2:CS Amplifier

1. OP and AC Analysis

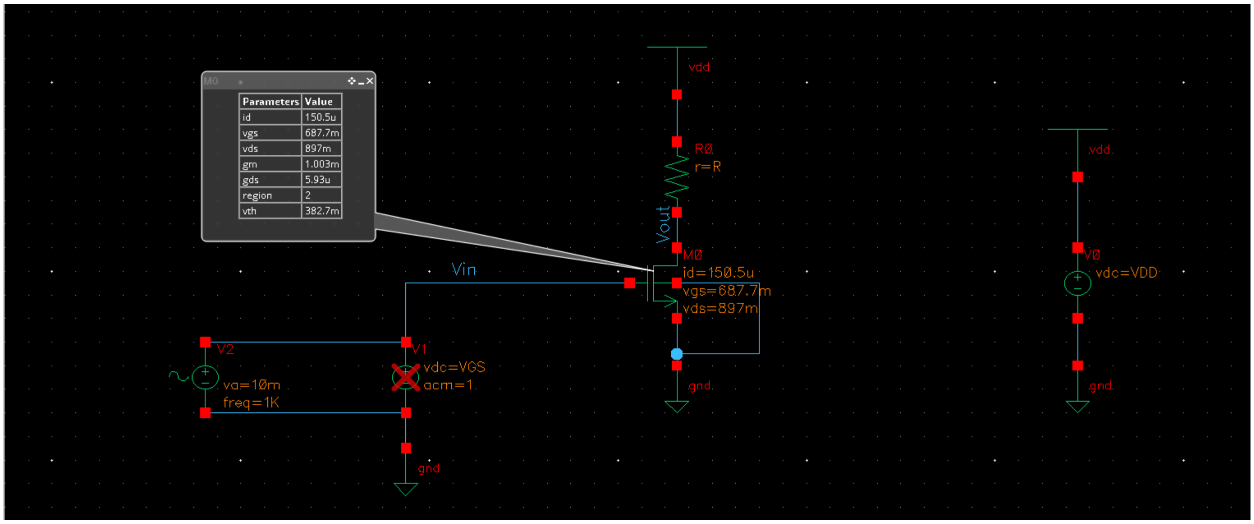

Figure 4 operating point in cs amplifier

Parameter	Part 1	CS amplifier
I_D	150µA	150.5µA
gm	$999.782\mu S$	1.003mS
gds	$5.9087\mu S$	5.93µS
r_o	$169.241K\Omega$	168.634KΩ
V_{GSQ}	$687.6579mV$	687.7mV

• 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) $r_o = 168.634K\Omega$ >>>RD=6KΩ

$R_{OUT} = r_o||RD$=5.8KΩ 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 $\frac{1}{L}$ $\therefore r_o \ \alpha \ L$.

• Intrinsic gain of MOSFET will be:

$A_v = -gm * r_0 = -169.14.$

• Amplifier gain analytically:

$A_v = -gm * (r_0||RD) = -5.81.$

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 =5.813

DC gain in dB =15.29

This values meets specs .

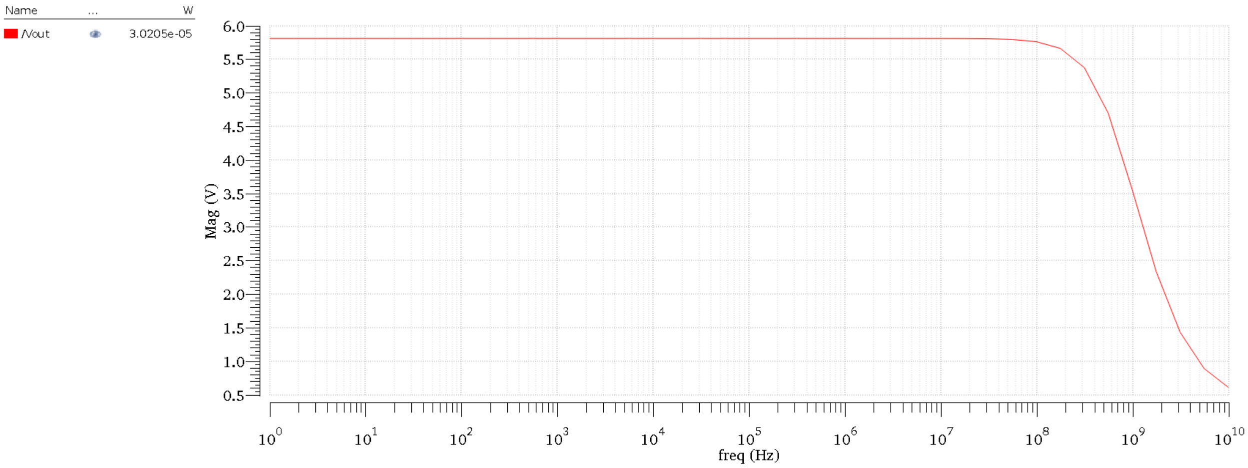

Figure 5 plot gain vs Frequency

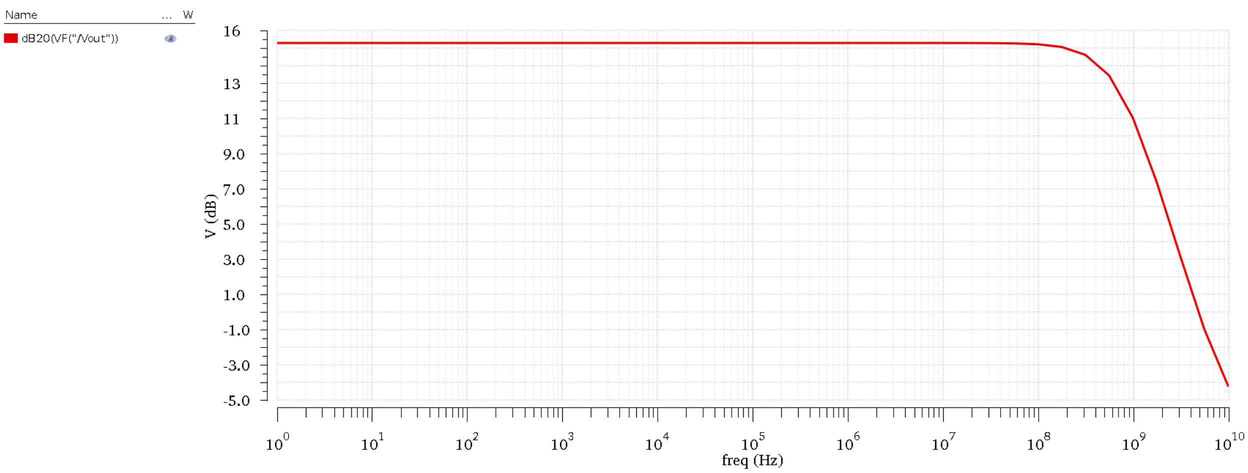

Figure 6 plot gain in dB VS Frequency

Test	Output	Nominal	Spec	Weight	Pass/Fail
LAB02:Common_Source:1	Vout				
LAB02:Common_Source:1	dB20(VF("/Vout"))				
LAB02:Common_Source:1	ymax(dB20(VF("/Vout")))	15.29			
LAB02:Common_Source:1	ymax(mag(VF("/Vout")))	5.813			

Figure 7 values of gain from simulator

2. Gain Non-Linearity

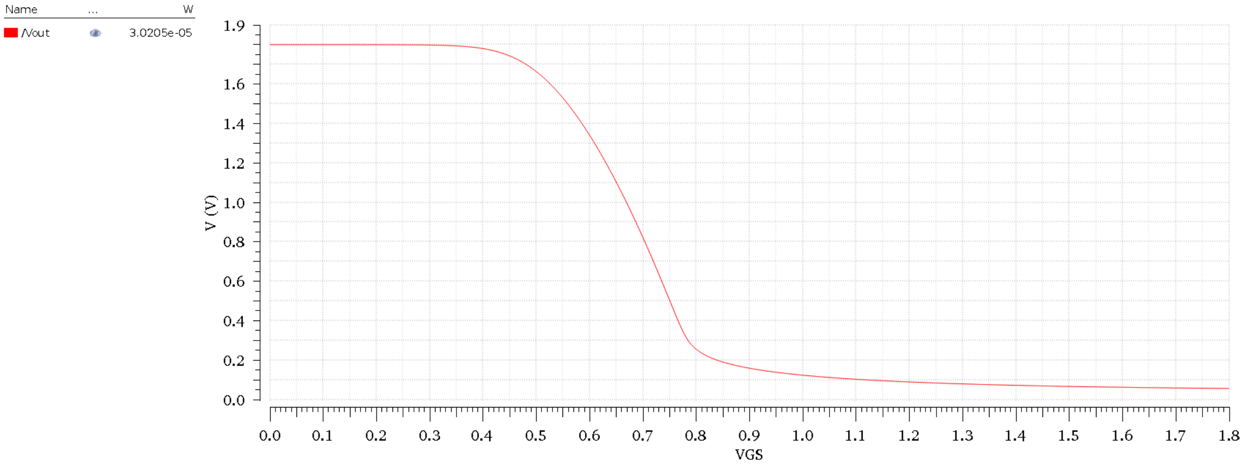

Figure 8 Vout Vs Vin in DC Sweep

•The relationship is not linear because The MOSFET's gm is not constant and gain =gm*RD. It decreases as V_{GS} increases. This is because the MOSFET's channel becomes narrower as V_{GS} increases, which reduces the number of carriers that can flow through the channel. The MOSFET enters the saturation region when $V_{GS}$is too large. In the saturation region, the drain-source current is nearly constant, so V_{OUT} is no longer proportional to Vin.

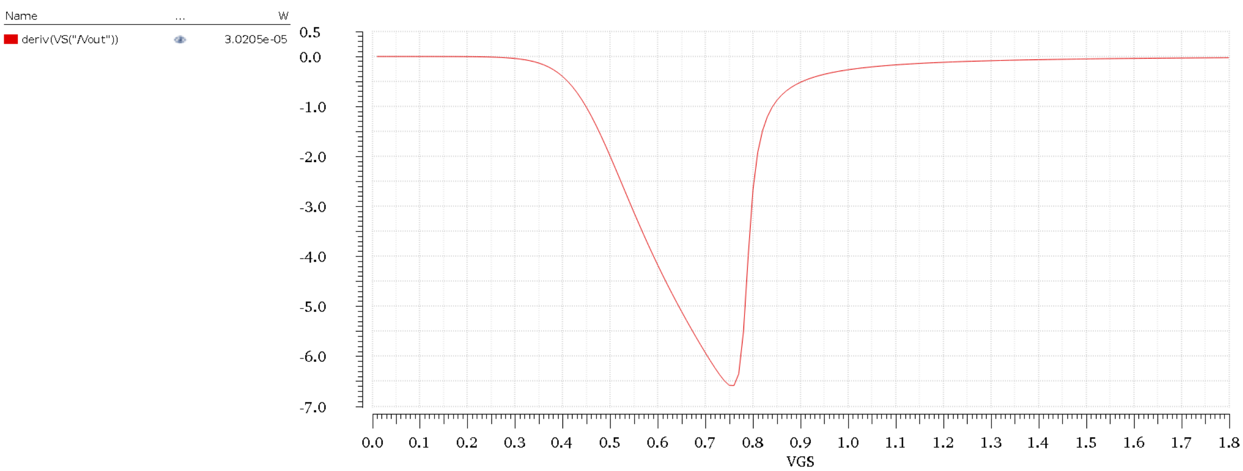

Figure 9 derivative of Vout vs Vin

•The figure shown in Figure 9 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 transconductance (gm), is dependent onV_{GS}.

Transient analysis:

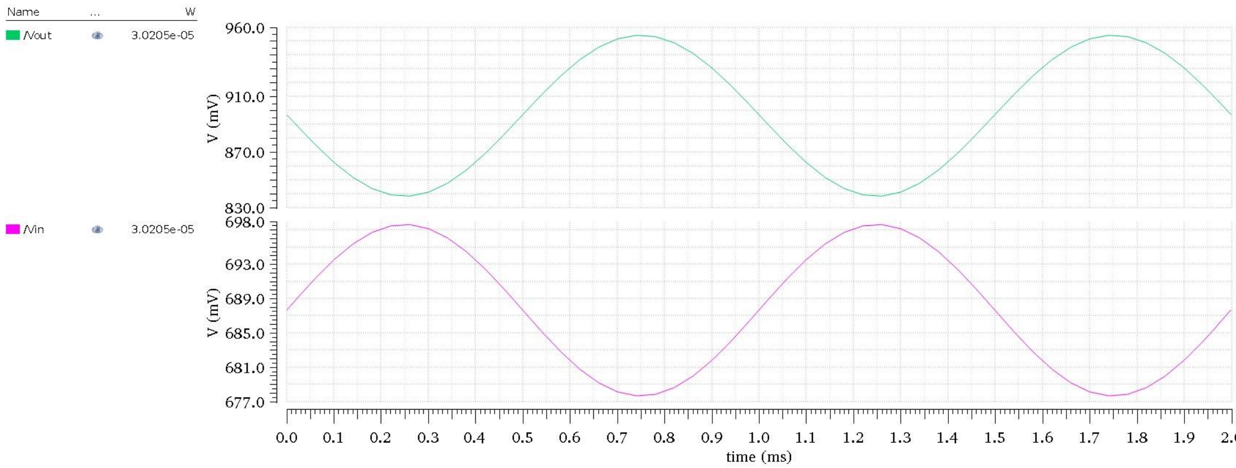

Figure 10 transient anlysis of Vout and Vin

Plot gm in transient analysis

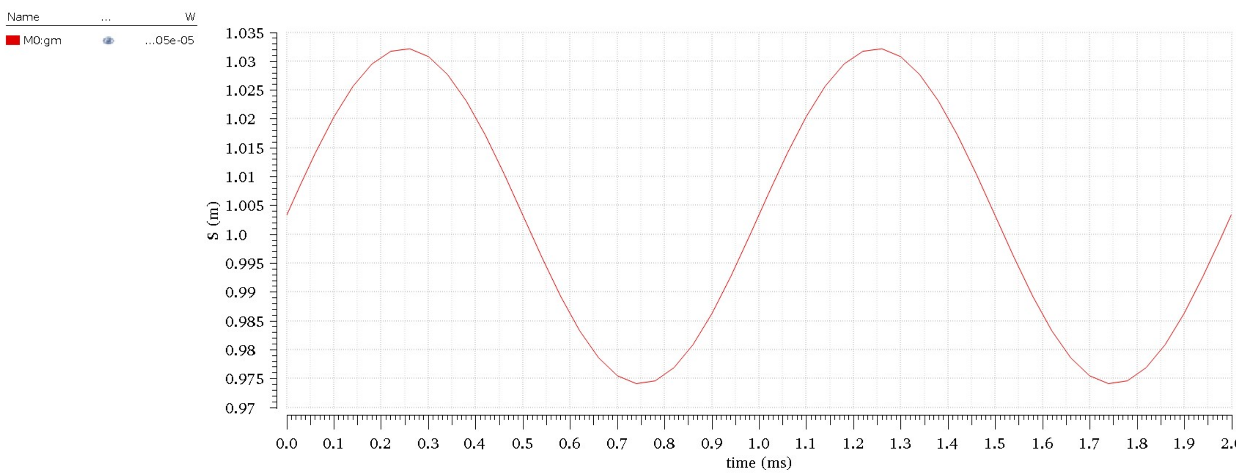

Figure 11 plot gm in transient analysis

5)as shown figure 11, 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.