# ITI

# LAB2

# Common Source Amplifier

## Contents

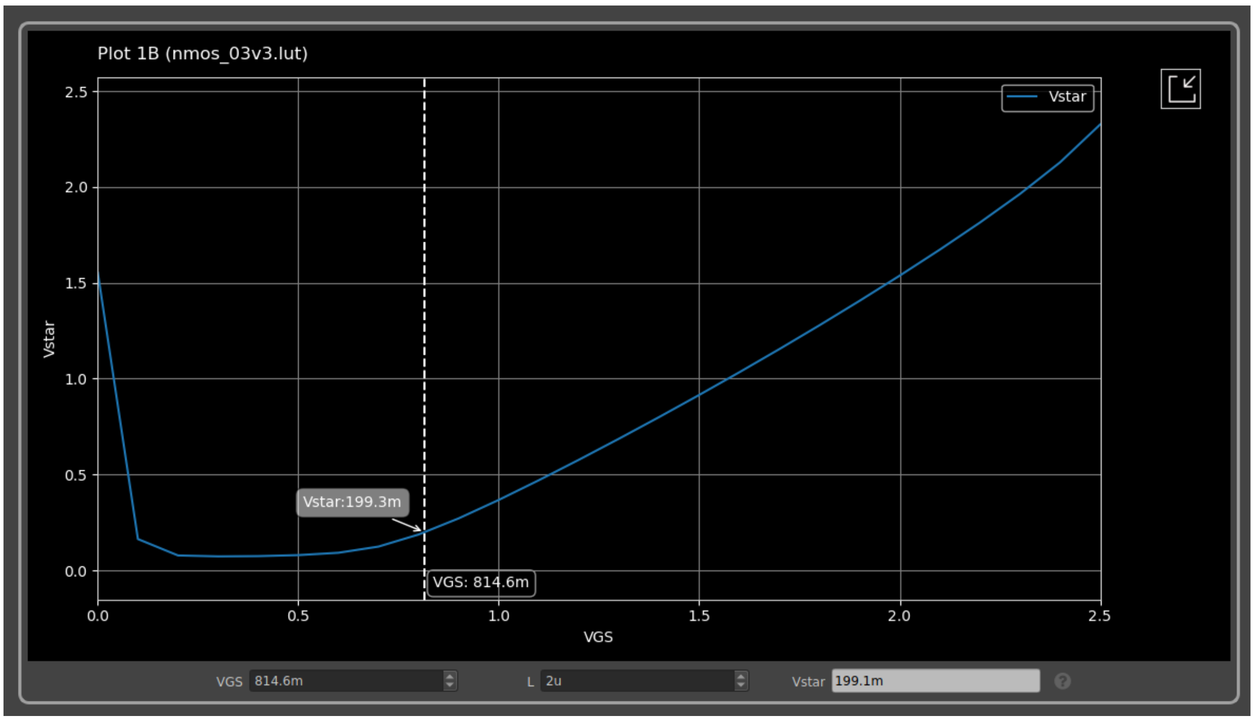
# Part1: Sizing Chart

Since that the requirements is to make the gain=-10 and the gain for the common source amplifier≈ $-g_m R_d$ which could be written as $\frac{g_m}{I_D} \times R_d I_D$ and $R_d I_D = V_{Rd}$ which was given to be 1V $V^* = 0.25V$

$I_D = 10\ \mu A$

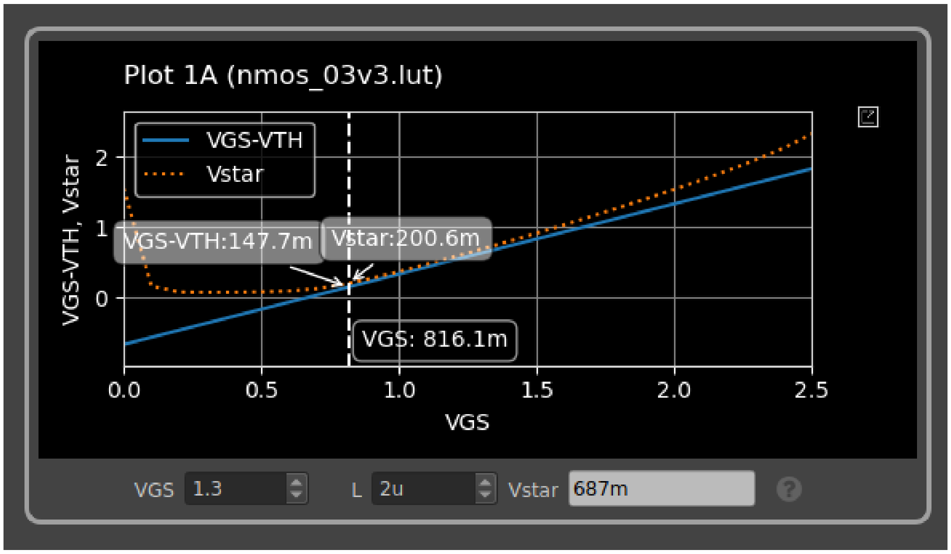
$R_D \times I_D = 1V$

$R_D = 100\ K\Omega$



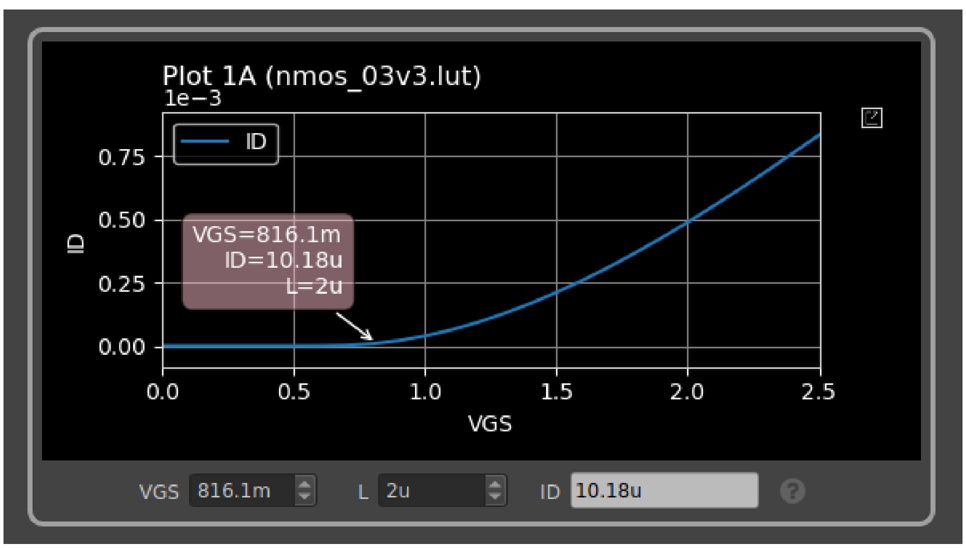

And from the graph we were able to find the value of $V_{gsQ} = 0.8146V$

Vstar and Vov overlaid(at $V_{gsQ} = 0.816V$ )

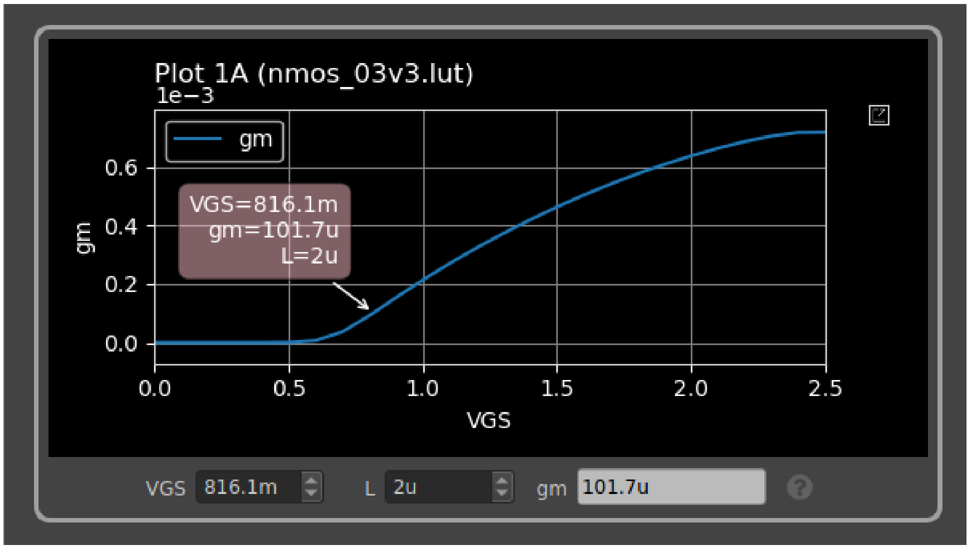



And from this graph the value of $V_{ovQ} = 147.7\ mV$

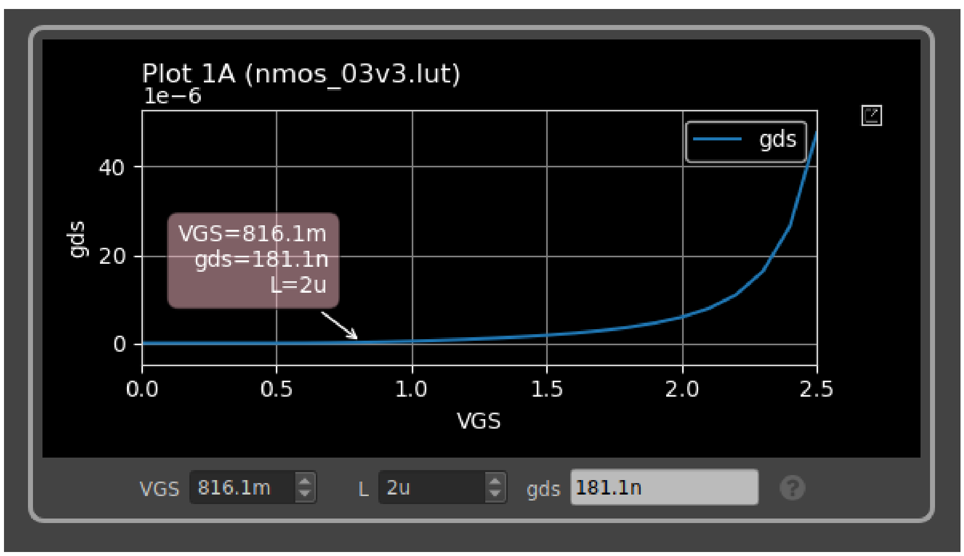
$I_{Dx}$



$g_{mx}$




$g_{dsx}$




# Cross-Multiplication

Now we will obtain the value of W ,$g_{mQ}$ and $g_{dsQ}$ using W=10$\mu m$ , $g_{mx}$ and $g_{dsx}$ and $I_{Dx}$

$$10\mu m \Rightarrow 10.18\ \mu A$$

$$W \Rightarrow 10\mu A$$

Then W=$9.82\mu m$

Now we will use the same concept to find the value of $g_{mQ}$ and $g_{dsQ}$

$g_{mx} = 101.7\mu S$ ,$g_{dsx} = 181.2nS$

$$101.7\mu S \Rightarrow 10.18\ \mu A$$

$$g_{mQ} \Rightarrow 10\mu A$$

$g_{mQ} \approx$ 100 µS

$$181.2nS \Rightarrow 10.18\ \mu A$$

$$g_{mQ} \Rightarrow 10\mu A$$

$g_{dsQ}$ = 178 nS

## $A_v$

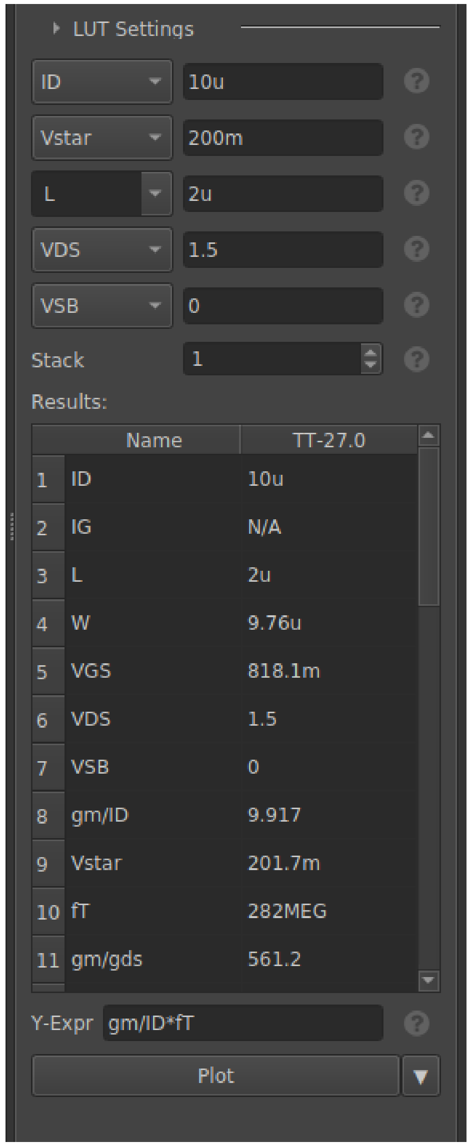
Now we will calculate the gain analytically to check if it meets the required gain

$Av = -g_m\ (ro\ //\ Rd)$

$r_o = \frac{1}{g_{ds}}$

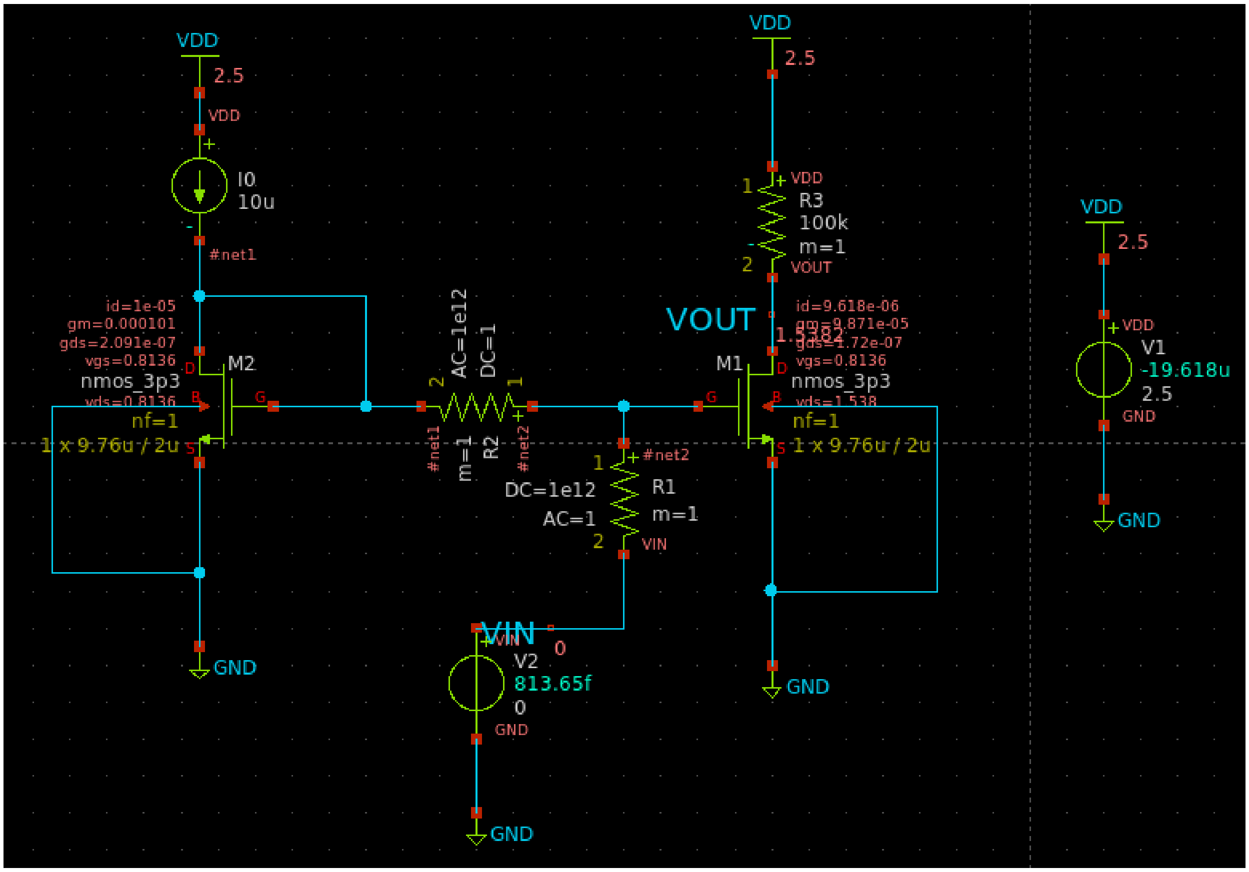
$Av$ =-9.825

# Sizing chart




| Parameter | Size(from graphs and cross-multiplications) |
|---|---|
| W | $10\mu m$ |
| L | $2\mu m$ |
| $V_{gs}$ | 816.1mV |
| $I_D$ | $10.18\ \mu A$ |
| $g_m$ | 100 µS |
| $g_{ds}$ | 178 nS |
| $V^*$ | $200\ mV$ |
| $V_{ov}$ | $147.7\ mV$ |

# PART 2: CS Amplifier Schematic




## DC-operating point

| Parameter | Obtained value from part1 | Obtained value from part2 |
|---|---|---|
| $I_D$ | $10\ \mu A$ | $9.618\ \mu A$ |
| $g_m$ | $99.17\mu S$ | $98.71.mS$ |
| $g_{ds}$ | $176.7nS$ | $172nS$ |

As the table shows all the parameters match the obtained results with a maximum error of 2.6%

## Comparing $r_o$ $and$ $R_D$

The value of $r_o$ $=$5.66 MΩ and $R_D = 100K\Omega$

Meaning $r_o \approx 56.6\ R_D$

If we lower the value of L the channel length effect starts to appear more which will lead to decreasing the value of $r_o$ making it comparable to comparable to $R_D$

## Intrinsic gain

The intrinsic gain of this circuit is 570 which is calculated using the equation

@m.xm1.m0[gm] / @m.xm1.m0[gds]

```
No. of Data Rows : 1
intrinsic_gain_m1 = 5.699197e+02
```

calculating the intrinsic gain analytically

$A_v = g_m r_o$ , $g_m = 99.17\mu S$ and $r_o = 5.66$ MΩ

$A_v(intrinsic) = 561.3$

calculating the gain analytically

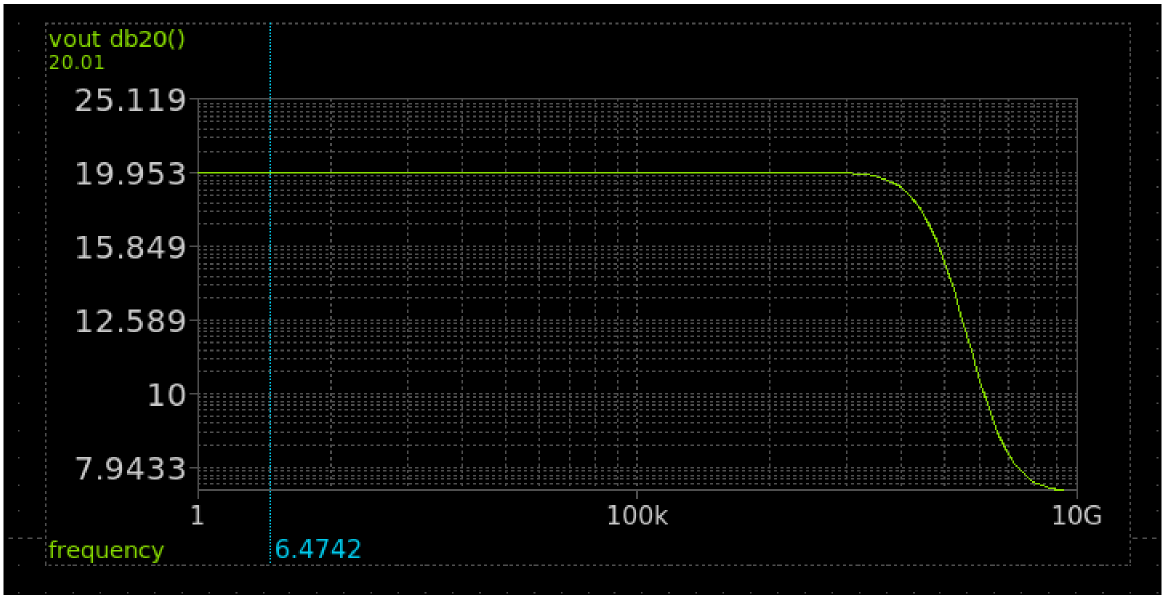
$A_v = g_m(r_o//R_D)$ , $g_m = 99.17\mu S$ and $r_o = 5.66$ MΩ and $R_D = 100K\Omega$

$A_v = 99.17(5.66//0.1)$

$A_v \approx 9.75$

Which means $A_v(intrinsic)$ >>$A_v$

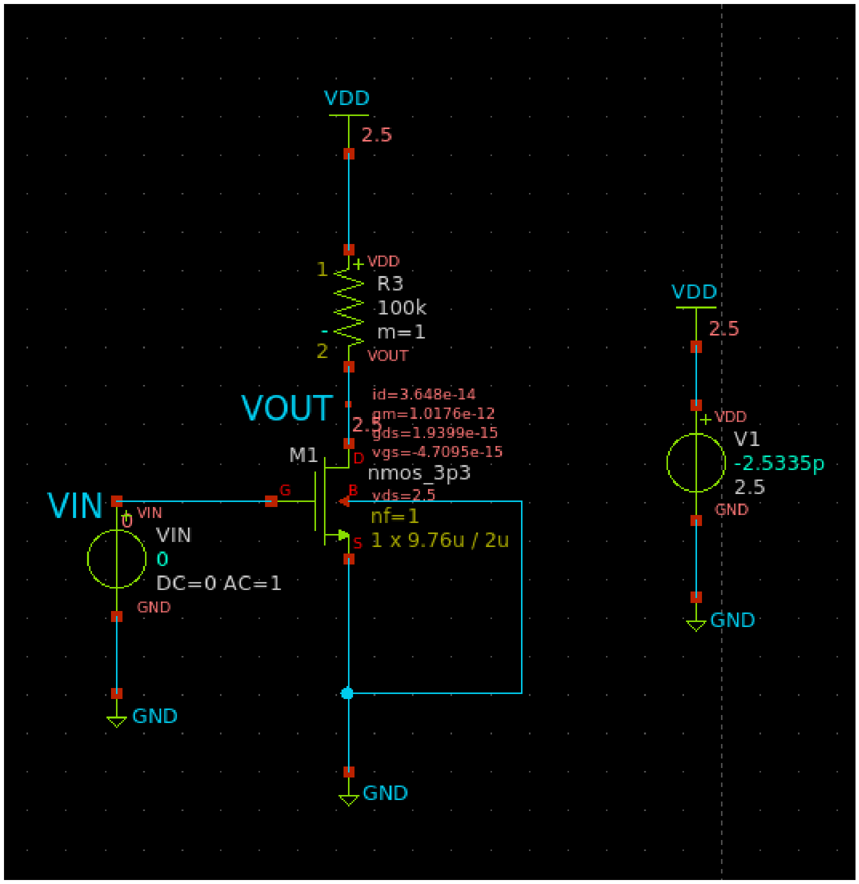
## Gain vs frequency

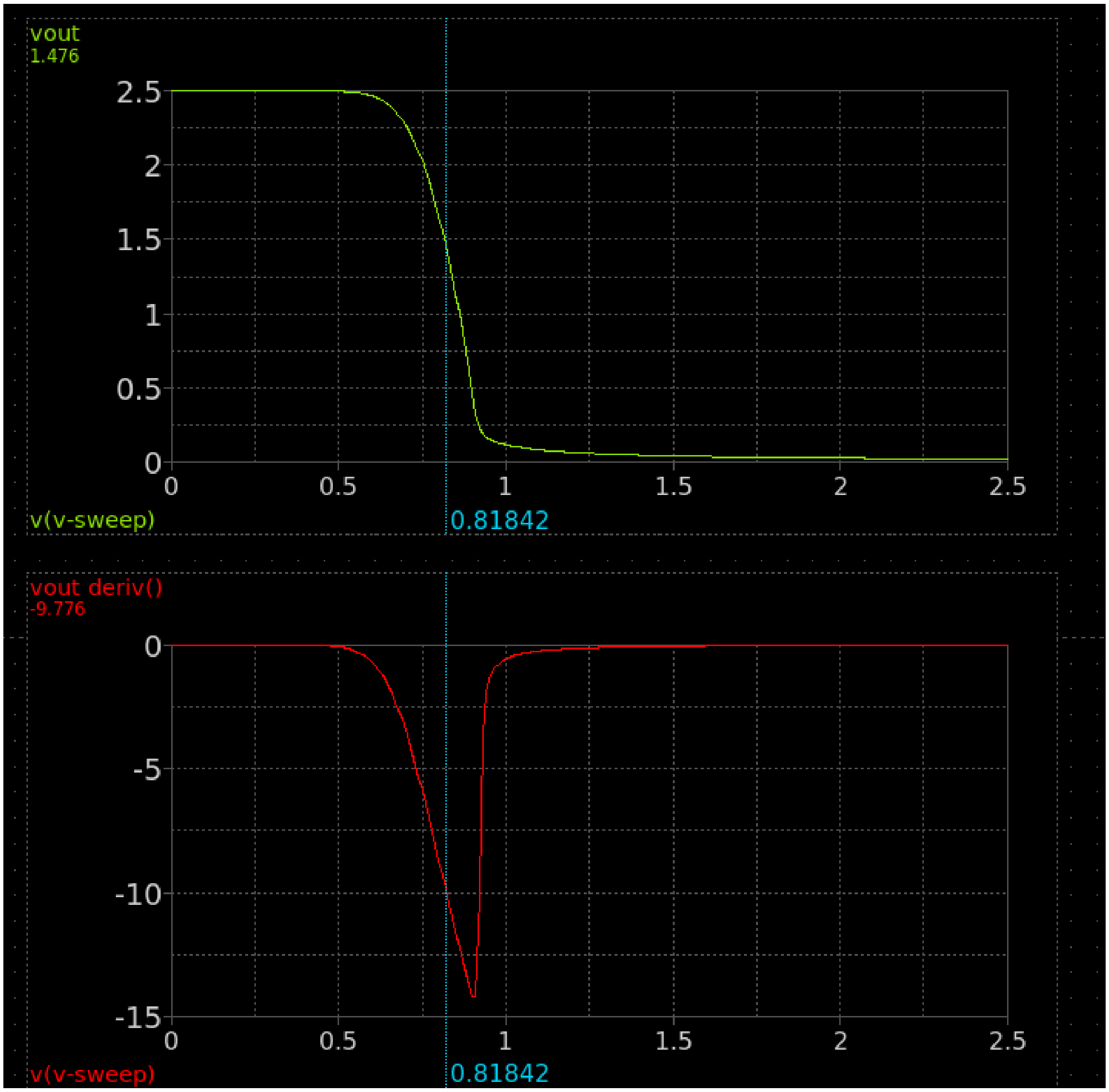



Comment: The gain vs. frequency plot shows that the amplifier maintains a nearly constant gain over a wide range of low frequencies, indicating good small-signal linearity in that region. However, at the –3 dB frequency the gain starts to drop significantly. This marks the beginning of the amplifier's high-frequency roll-off, primarily due to internal capacitances and the limited speed of the MOSFET. Beyond this point, the amplifier is no longer effective at amplifying signals without distortion or attenuation.

## Gain Non-Linearity (Large Signal Operation DC Sweep)

### Schematic






Comment:

1. The VOUT vs. VIN plot shows a nonlinear relationship. Initially, as Vin increases, Vout decreases gradually, but after a certain threshold, the output drops rapidly. This nonlinearity occurs because the MOSFET transitions through different regions of operation — from cutoff to saturation, and eventually to triode. In the saturation region, small changes in Vin cause large changes in Vout , which results in the steep slope. Thus, the amplifier operates linearly only over a small range of input voltages near the Q-point; outside this range, the behavior is strongly nonlinear due to the MOSFET's inherent characteristics.

2. The derivative of Vout with respect to Vin was calculated using the Cadence Calculator, and the resulting plot of derivative of Vout vs. Vin represents the small-signal gain of the

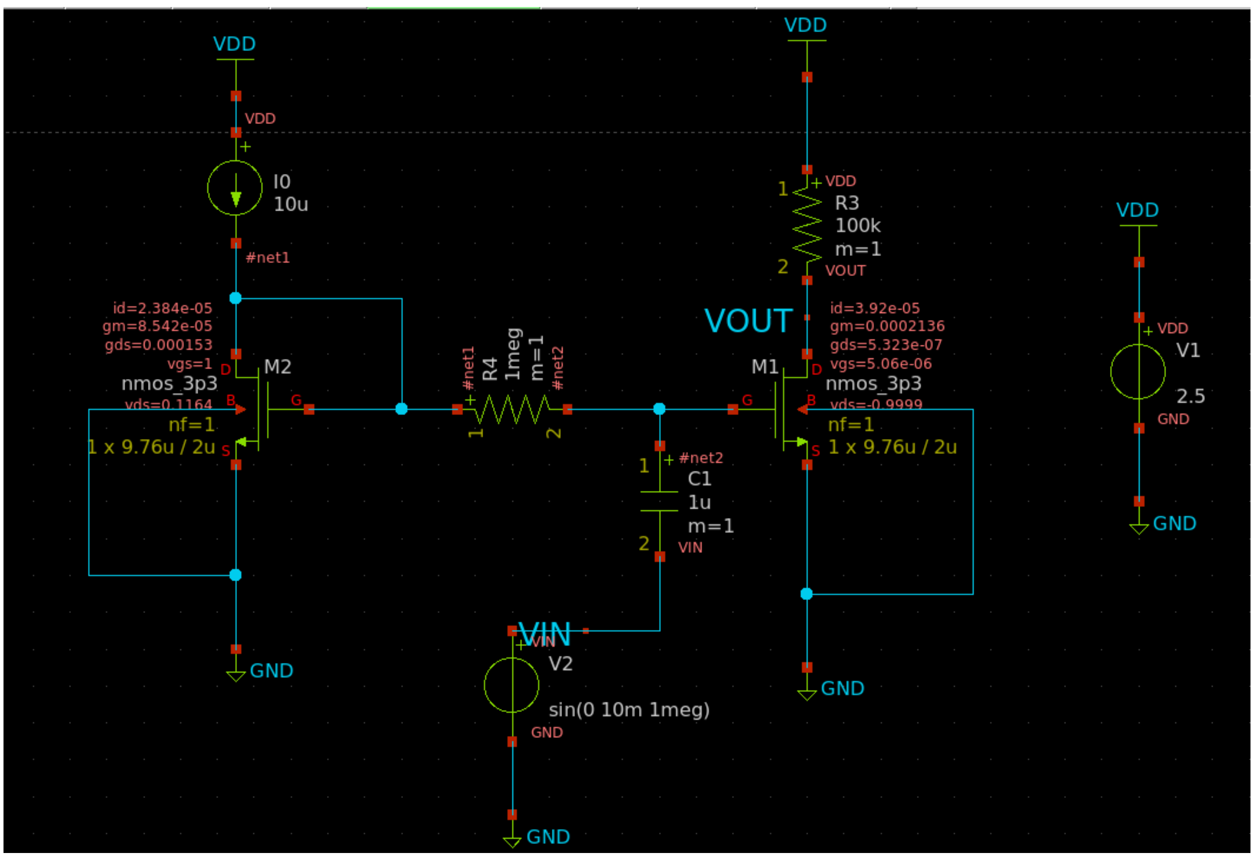
amplifier. The plot shows that the gain is not constant across all input voltages — it is high only within a narrow region around the chosen bias (Q-point), and drops off sharply outside that range.

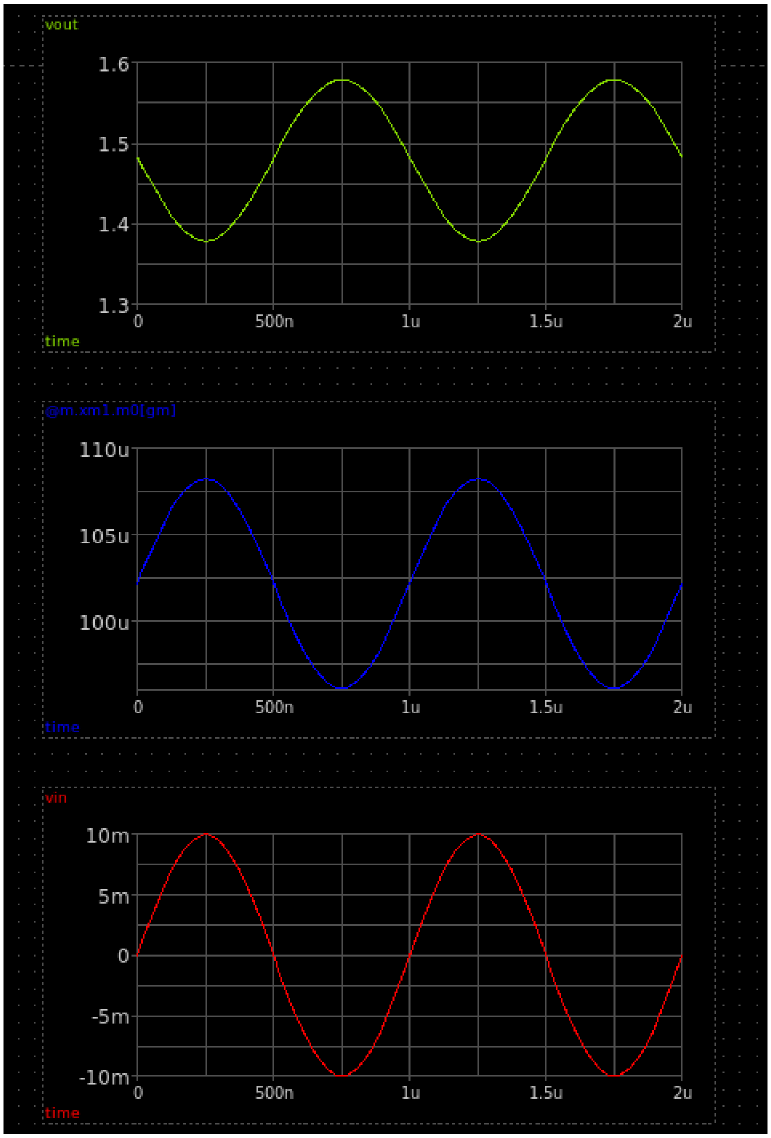
This behavior confirms that the amplifier is only linear in a small region near the Q-point. In this region, the transistor operates in saturation, where gm is relatively stable, resulting in a well-defined and predictable gain. However, as VIN moves away from the Q-point:

- At low Vin the MOSFET enters cutoff, causing gain to approach zero.
- At high Vin, the device moves into the triode region, also degrading the gain.

Thus, the gain is not independent of the input; it varies strongly with Vin except near the Q-point. This emphasizes the importance of carefully biasing the MOSFET to ensure linear operation in analog amplifier design.

## Gain Non-Linearity (Transient Analysis)






Comment:

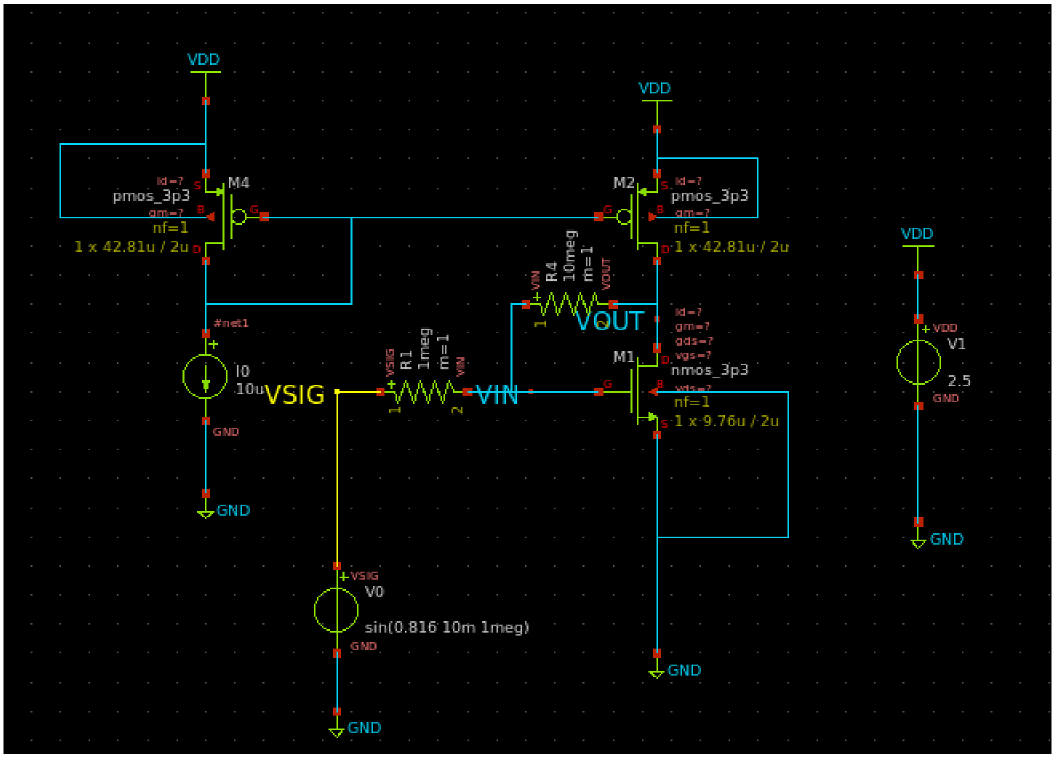
Gm varies with the input signal because it depends on Vgs, which changes as the input changes. This means the gain of the amplifier also varies, leading to nonlinear distortion if the input signal is too large. For accurate small-signal operation, the input should be limited to a range where gm can be considered approximately constant around the Q-point.

## Is this amplifier Linear

This amplifier is nonlinear as from the transient simulation, the gm vs time plot shows a sinusoidal variation, this indicates that the circuit is nonlinear, since in a linear amplifier, $g_m$ should remain constant. The observed $g_m$ fluctuation confirms the dependency of transconductance on the input signal amplitude, which is a typical characteristic of MOSFET-based amplifiers in large-signal conditions.

## Gain Linearization (Negative Feedback)

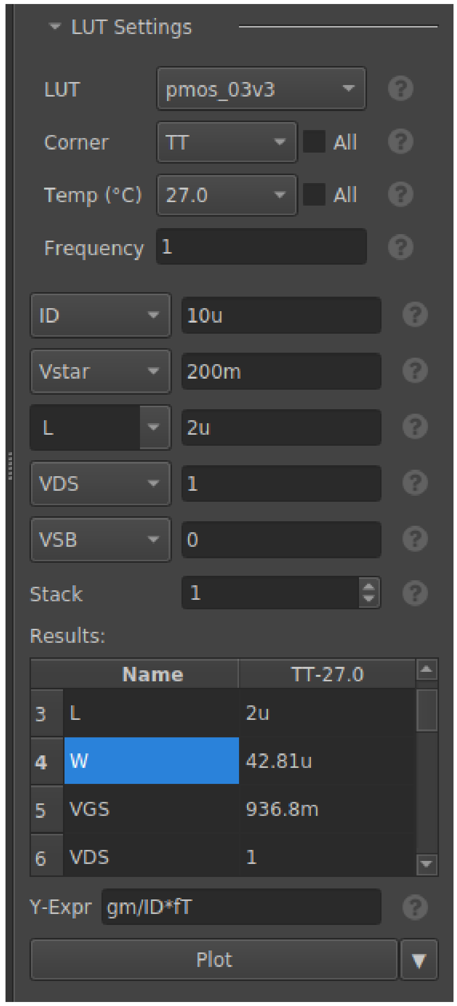
### Schematic

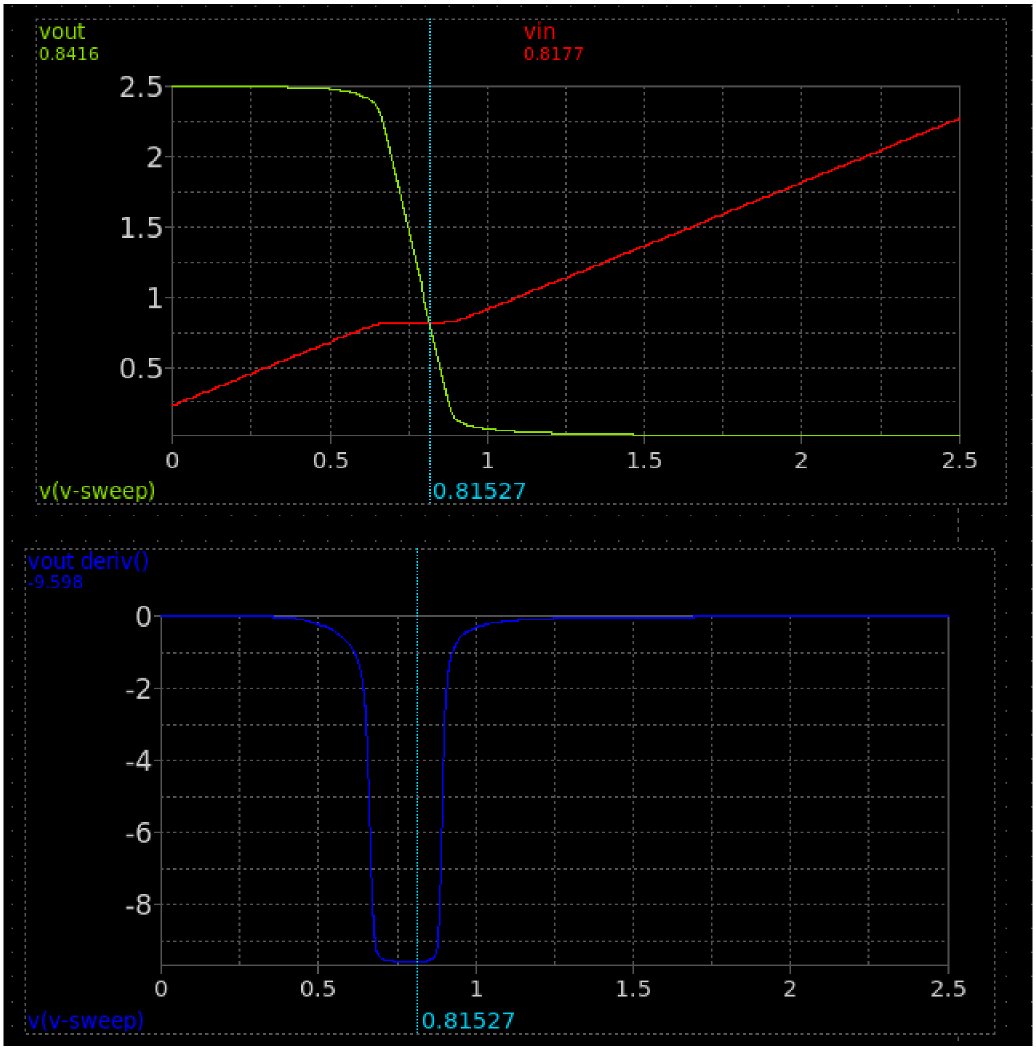



$$R_{in} = \frac{R_F}{A_v}$$

Then $R_{in} = 1M\Omega$

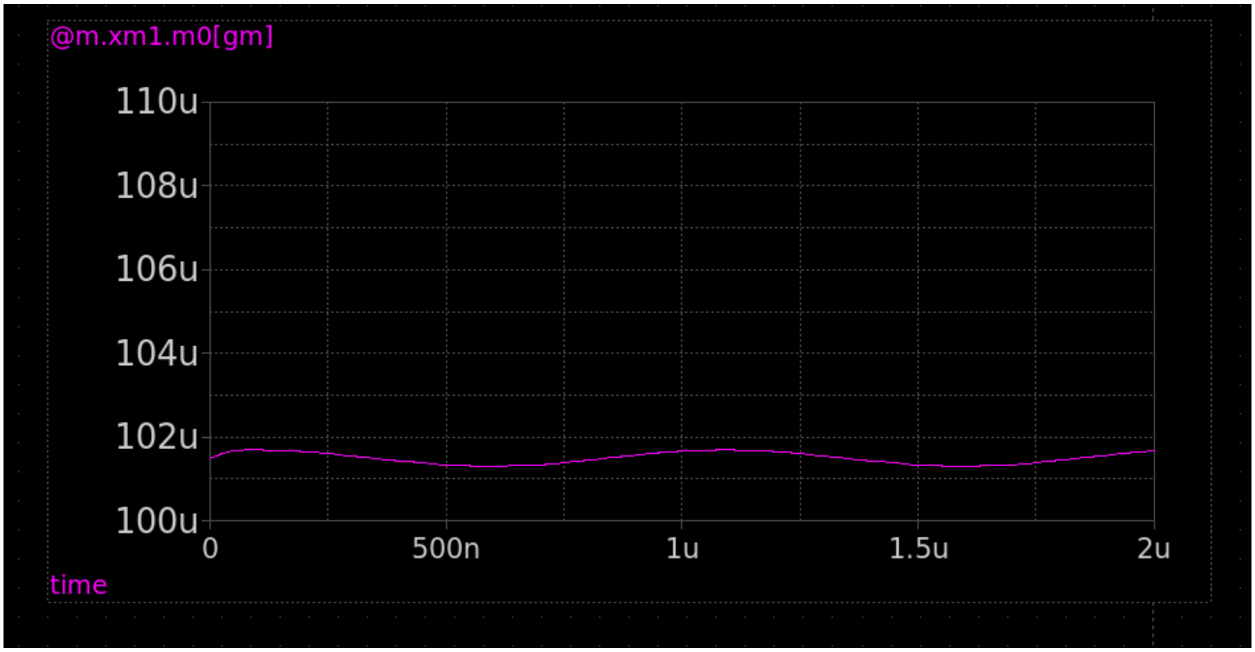
# ADT results


LUT Settings
LUT
pmos_03v3
Corner
TT
All
Temp (°C)
27.0
All
Frequency
1
ID
10u
Vstar
200m
L
2u
VDS
1
VSB
0
Stack
1
Results:
Name
TT-27.0
3
L
2u
4
W
42.81u
5
VGS
936.8m
6
VDS
1
Y-Expr
gm/ID*fT
Plot




Comment: The curves of VIN and VOUT cross at the point where the input signal equals the quiescent gate voltage of M1. At this point, VOUT = VIN , and no current flows in the feedback resistors. This point represents the bias point of the amplifier, where the system is balanced, and the MOSFET operates at its designed operating point ($V_{gs_Q}$)

## $g_m$ vs time




Comment: By running the transient simulation, the gm vs time plot for the feedback amplifier shows that the $g_m$ matches exactly the gm of the resistive-loaded open-loop amplifier, confirming that both circuits operate at the same quiescent transconductance. However, the variation of $g_m$over time is significantly lower in the feedback circuit due to the stabilizing effect of negative feedback. This reduced gm fluctuation indicates improved linearity, as the feedback minimizes the impact of input signal changes on the transistor's operating point, keeping gm more constant compared to the open-loop case.