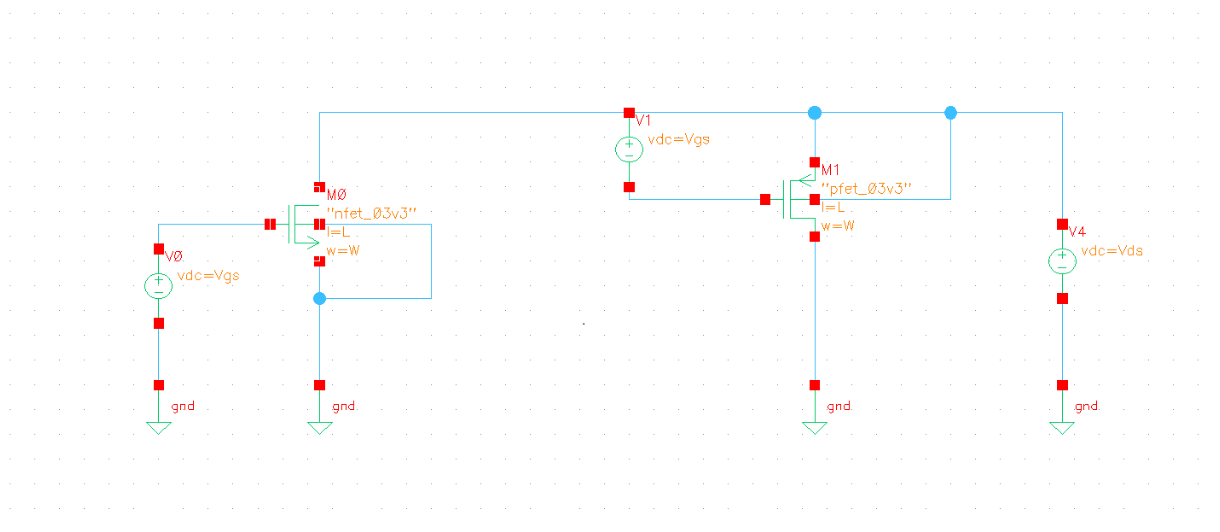
ITI

LAB2

Contents

Part1

Schematic



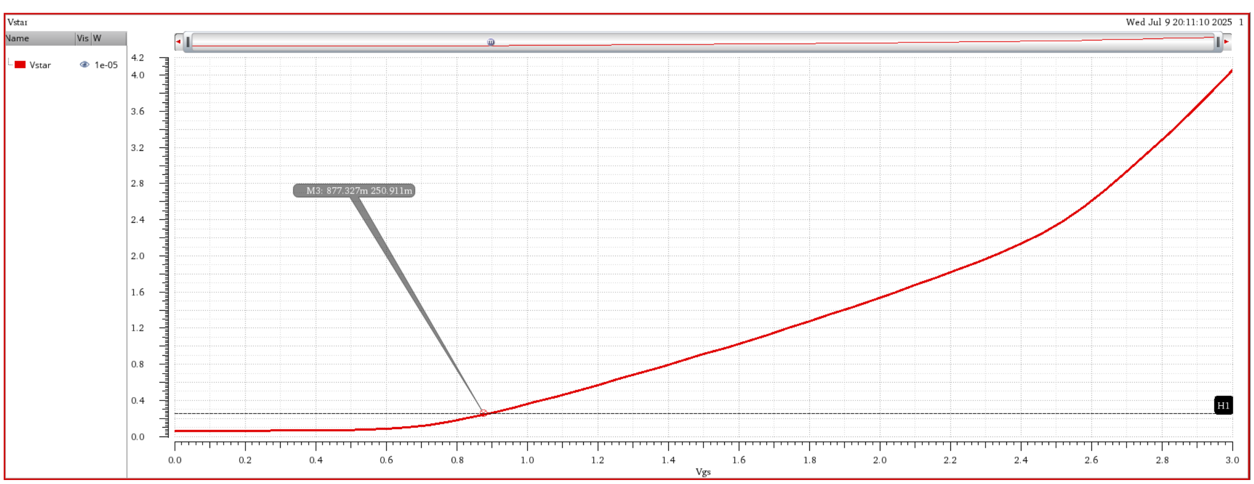
Sizing charts

Since that the requirements is to make the gain=-12 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 $\frac{Vdd}{2}$ so this will make the $V^* = 0.25V$

Also for V_{Rd} *to be* $\frac{Vdd}{2}$ with vdd=3V and $I_D = 200\ \mu A$

$$R_D \times I_D = \frac{Vdd}{2}$$

$$R_D = 7500\Omega$$

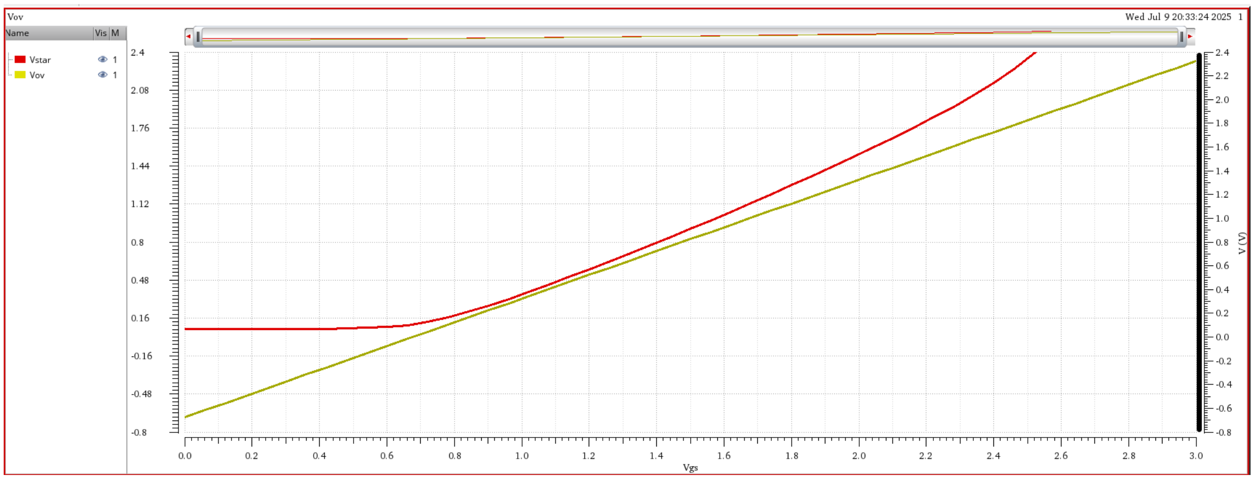


V^* equation ((2 * getData("M0:id" ?result "dc")) / getData("M0:gm" ?result "dc"))

Vov equation is (v("M0:vgs" ?result "dc") - v("M0:vth" ?result "dc"))

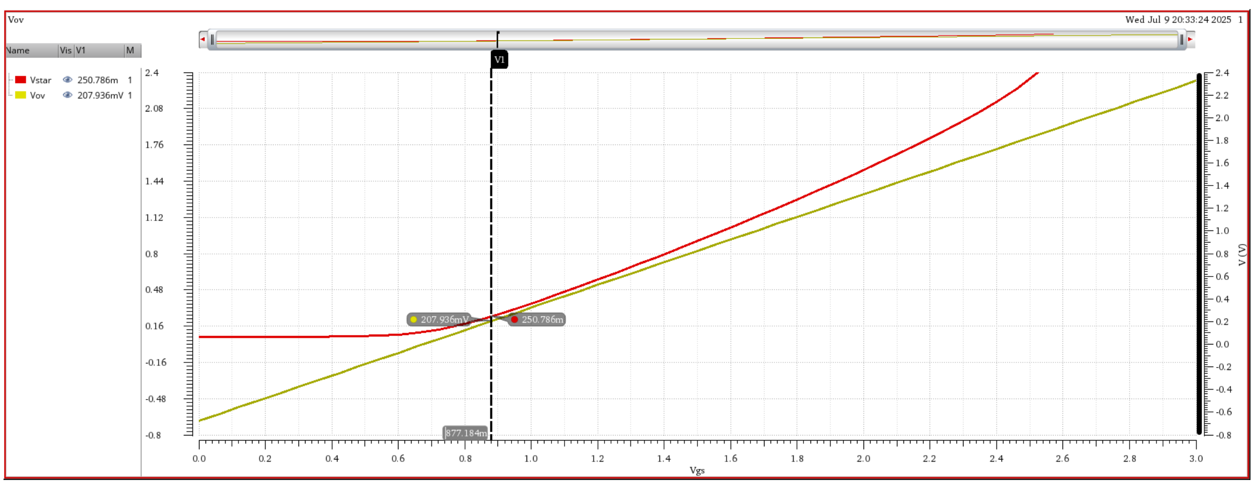
And from the graph we were able to find the value of $V_{gsQ} = 0.877V$

Vstar and Vov overlaid



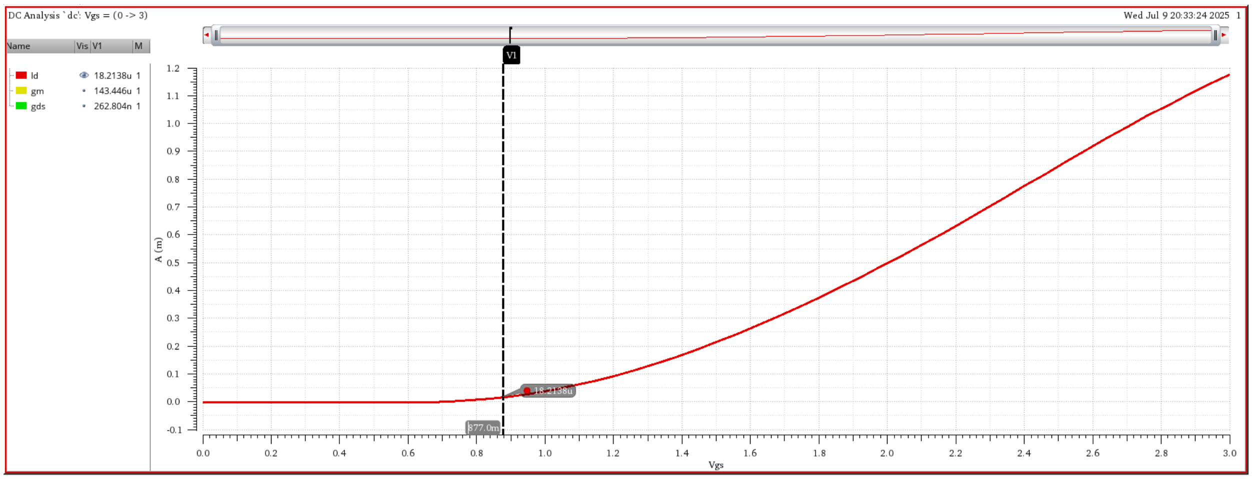
Vov equation is (v("M0:vgs" ?result "dc") - v("M0:vth" ?result "dc"))

Vstar and Vov overlaid (at $V_{gsQ} = 0.877V$)



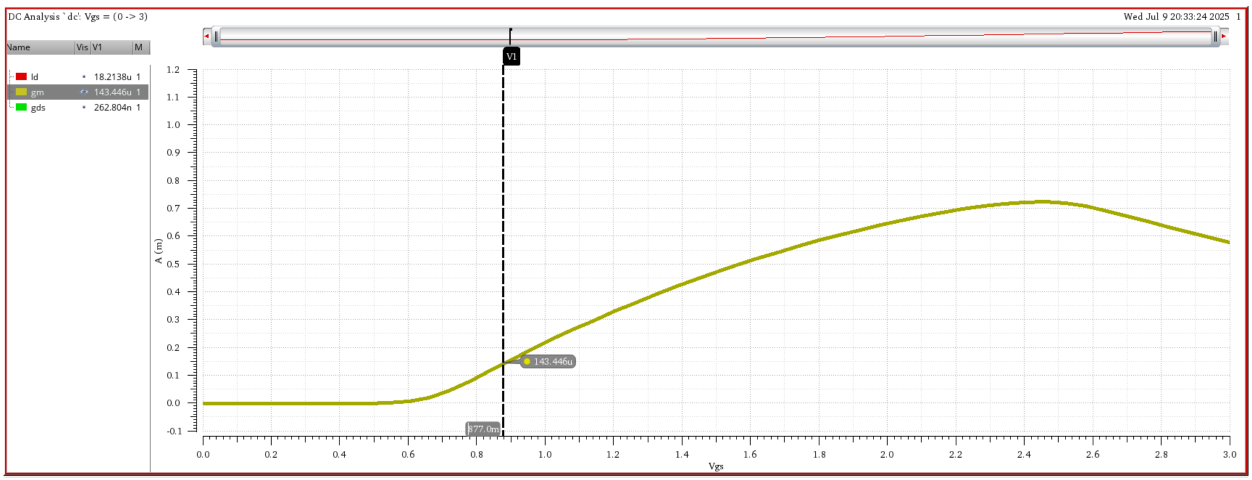
And from this graph the value of $V_{ovQ} = 207.9\ mV$

I_{Dx}



DC Analysis `dc': Vgs = (0 -> 3)
Wed Jul 9 20:33:24 2025 1
Name Vis V1 M
Id 18.2138u 1
gm 143.446u 1
gds 262.804n 1
V1
A (m)
18.2138u
877.0m
Vgs

g_{mx}



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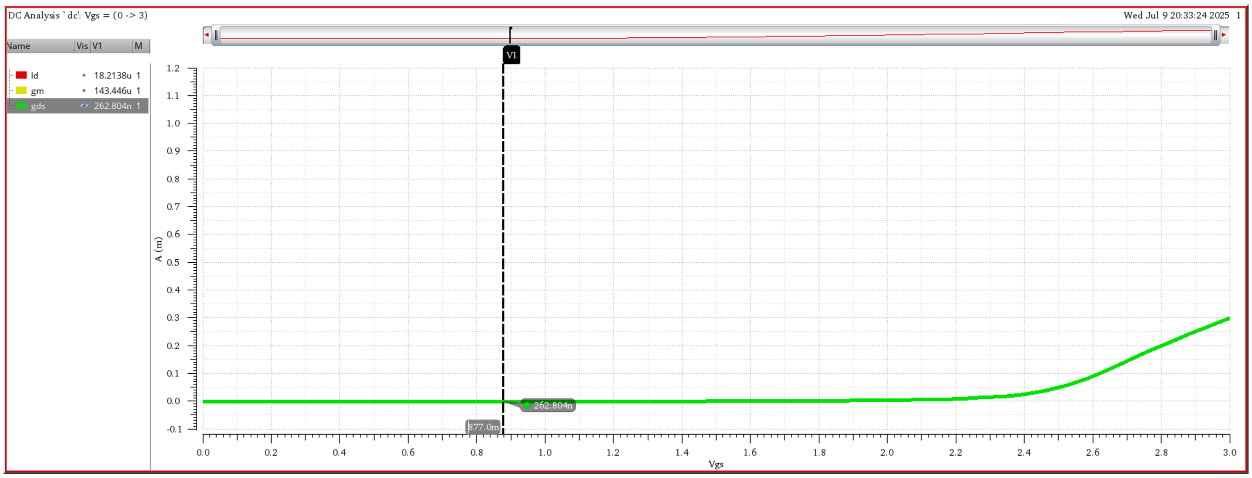


Cross-Multiplication

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

$$10\mu m \Rightarrow 18.2\ \mu A$$

$$W \Rightarrow 200\mu A$$

Then W=111μm but since the used transistor's maximum dimension is 111μm we will need to use another factor which is the number of multipliers to help us reach the desired W

So now we will use W=22.2μm and the number of Multipliers M=5

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

$g_{mx} = 143.446\mu S$,$g_{dsx} = 262.804nS$

$$143.446\mu S \Rightarrow 18.2\ \mu A$$

$$g_{mQ} \Rightarrow 200\mu A$$

$g_{mQ} \approx 1.6$ mS

$$262.804nS \rightarrow 18.2\ \mu A$$

$$g_{mQ} \rightarrow 200\mu A$$

$g_{dsQ} = 2.888\ \mu S$

A_v

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

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

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

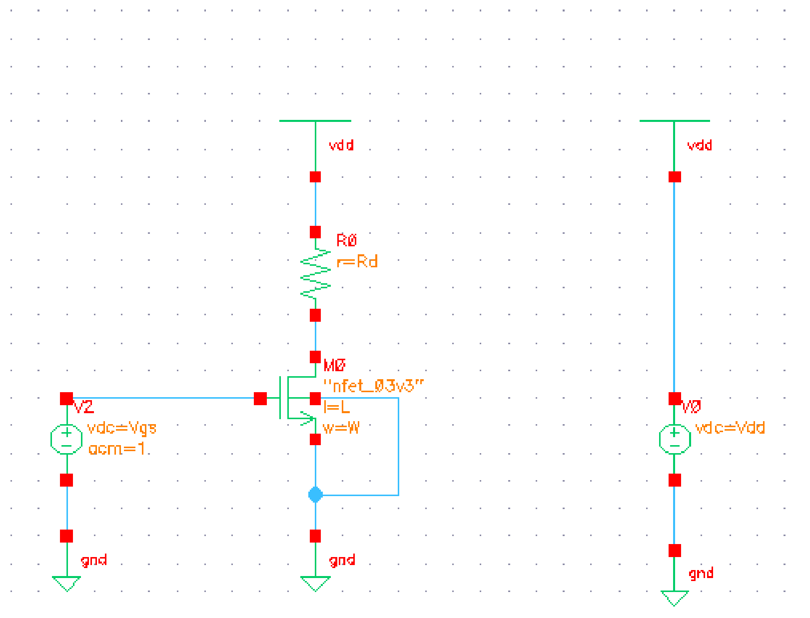
Av =-11.7455

Sizing chart

Parameter	Size
W	$10\mu m$
L	$2\mu m$
V_{gs}	877mV
I_D	$18.2\ \mu A$
g_m	$143.5\mu S$
g_{ds}	$262.804nS$
V^*	$250mV$
V_{ov}	$207.936mV$

Part2

Schematic



DC-operating point

Parameter	Obtained value from part1	Obtained value from part2
I_D	$199.4\ \mu A$	$199.4\ \mu A$
g_m	$1.575 mS$	$1.595 mS$
g_{ds}	$262.804 nS$	$261.804 nS$
V_{ov}	$207.936 mV$	207.8mV
r_o	346KΩ	344.2KΩ

As the table shows all the parameters match the obtained results with a maximum error of 1%

Test	Output	Nominal	Spec	Weight	Pass/Fail
ITI:LAB2P2:1	Id	199.4u			
ITI:LAB2P2:1	Vgs	877m			
ITI:LAB2P2:1	gm	1.595m			
ITI:LAB2P2:1	gds	2.905u			
ITI:LAB2P2:1	Region	2			
ITI:LAB2P2:1	ro	344.2k			

Id equation OP("/M0" "id")

Vgs equation OP("/M0" "vgs")

g_m equation OP("/M0" "gm")

Region equation OP("/M0" "region")

g_{ds} equation OP("/M0" "gds")

ro equation (1 / OP("/M0" "gds"))

Comparing r_o and R_D

The value of r_o $=$344.2KΩ and $R_D = 7500$Ω

Meaning $r_o \approx 46\ R_D$

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 548.9 which is calculated using the equation

((1 / OP("/M0" "gds")) * OP("/M0" "gm"))

ITI:LAB2P2:1	intrinsic gain	548.9			

calculating the intrinsic gain analytically

$A_v = g_m r_o$, $g_m = 1.595mS$ and $r_o = 344.2K\Omega$

$A_v(intrinsic) = 549$

calculating the gain analytically

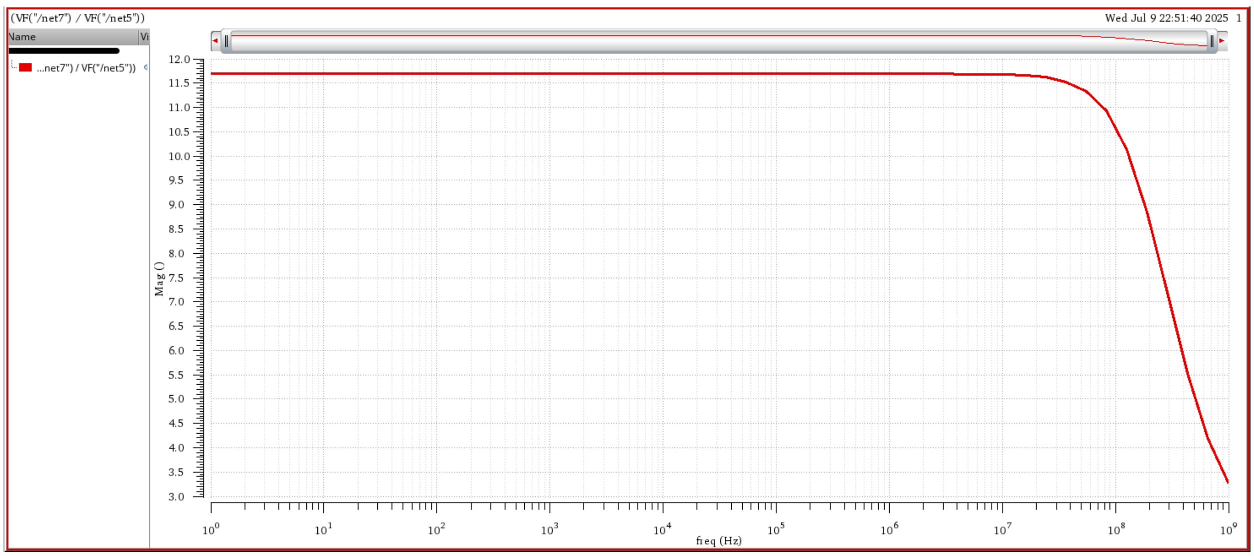
$A_v = g_m(r_o//R_D)$, $g_m = 1.595mS$ and $r_o = 344.2K\Omega$ and $R_D = 7500\Omega$

$A_v = 1.595(344.2//7.5)$

$A_v = 11.707$

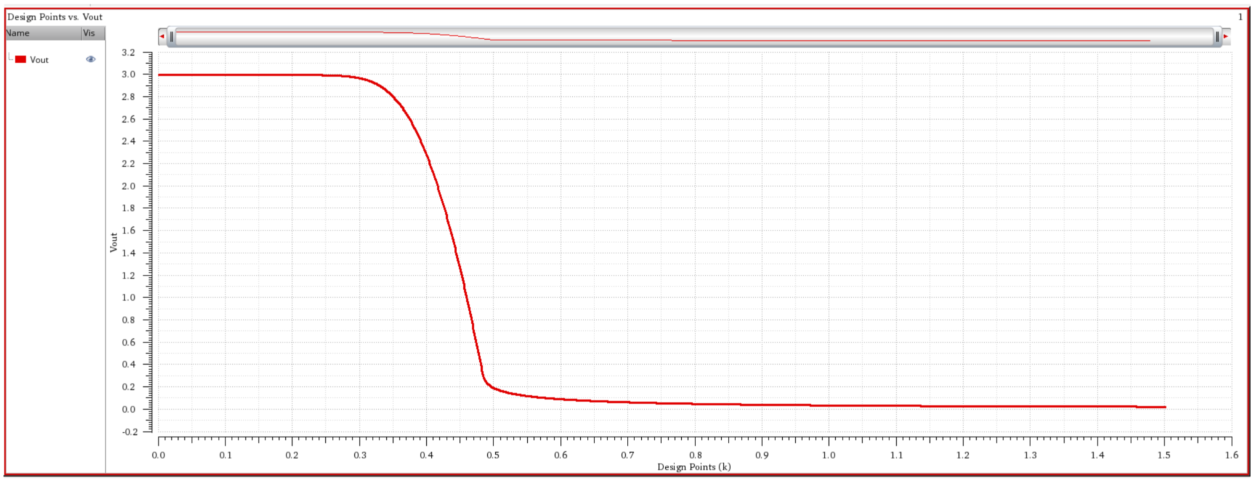
Which means $A_v(intrinsic)$ >>A_v

Gain vs frequency



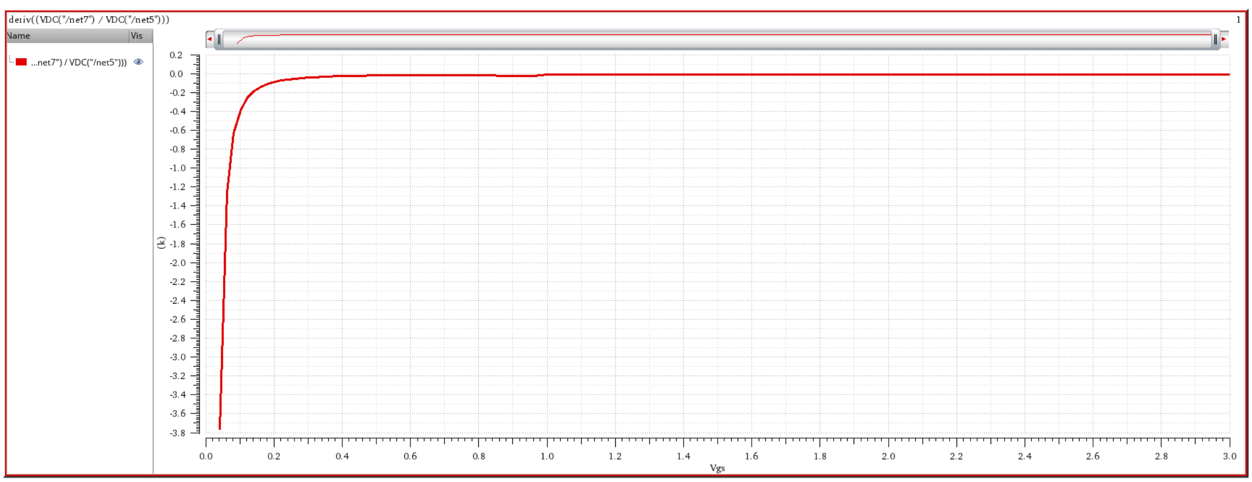
Gain equation (VF("/net7") / VF("/net5"))

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.



Comment:

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.



Comment:

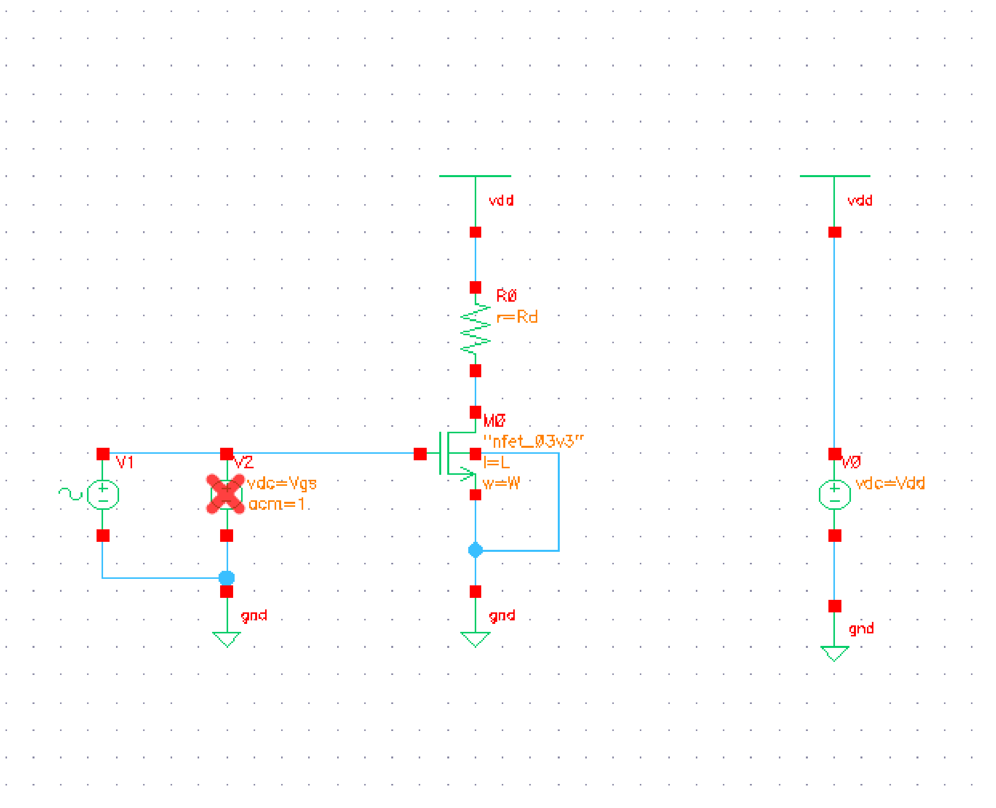
The derivative of Vout with respect to Vin was calculated using the Cadence Calculator, and the resulting plot of derivative of Vout vs. Vin represents the small-signal gain of the amplifier. The plot shows that the gain is not constant across all input voltages — it is high only within a narrow region around the chosen bias (Q-point), and drops off sharply outside that range.

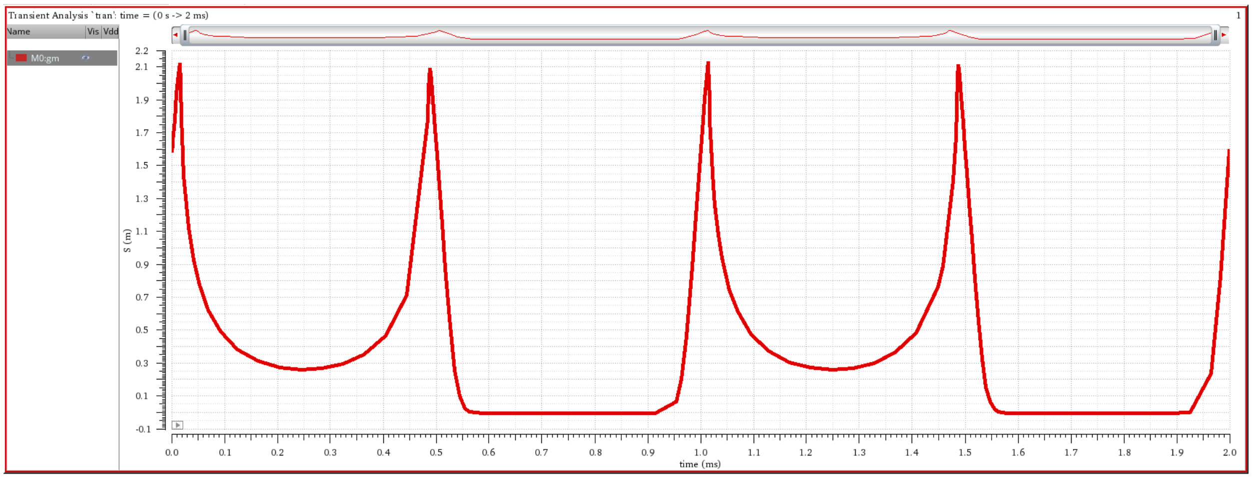
This behavior confirms that the amplifier is only linear in a small region near the Q-point. In this region, the transistor operates in saturation, where gm is relatively stable, resulting in a well-defined and predictable gain. However, as VIN moves away from the Q-point:

- 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.

Transient analysis





Comment:

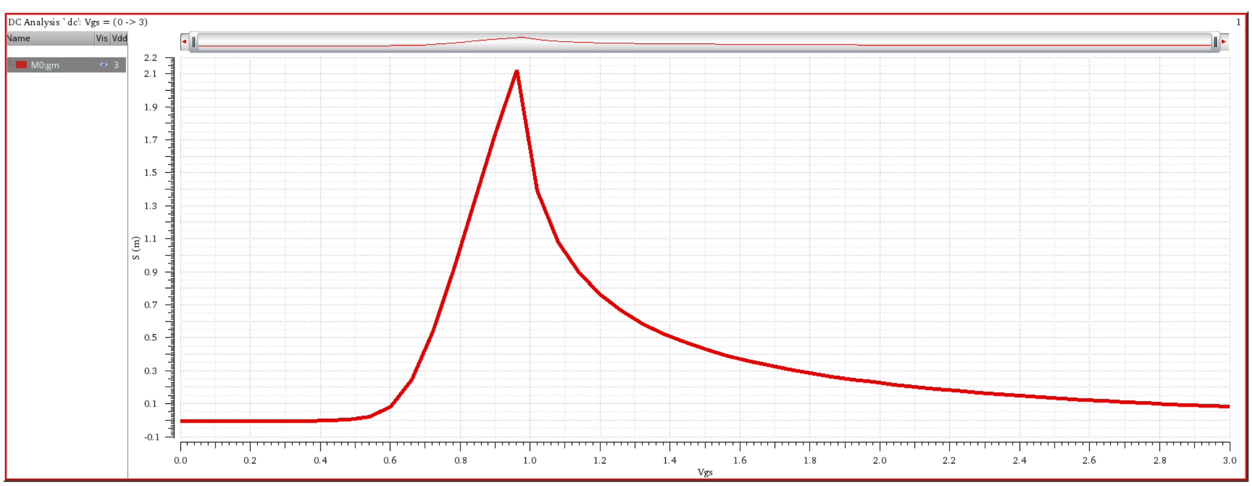
Gm varies with the input signal because it depends on Vgs, which changes as the input changes. This means the gain of the amplifier also varies, leading to nonlinear distortion if the input signal is too large. For accurate small-signal operation, the input should be limited to a range where gm can be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

Is this amplifier Linear

This amplifier is nonlinear, as seen from the VOUT vs VIN plot and the gain derivative plot. The output does not vary linearly with the input, and the gain is not constant across the input range. This is expected because the MOSFET transitions through cutoff, saturation, and triode regions depending on the input voltage, leading to significant variation in its operating characteristics.

In a common-source amplifier, the small-signal gain is given by:

$$A_v = -g_m \times R_D$$



To validate this, the transconductance gm was plotted against Vgs, and it was observed that gm changes significantly across the input sweep. It increases rapidly as the MOSFET enters strong inversion and then may level off or degrade due to mobility effects. This confirms that gm is not constant, which directly causes the gain to vary with the input — a clear sign of nonlinear behavior.

Therefore, this amplifier operates linearly only in a small region around the Q-point. Outside of that region, the gain changes with the input, leading to distortion in large signal conditions.