Analog IC Design – Cadence Tools
Lab 02
Common Source Amplifier

PART 1: Sizing Chart:

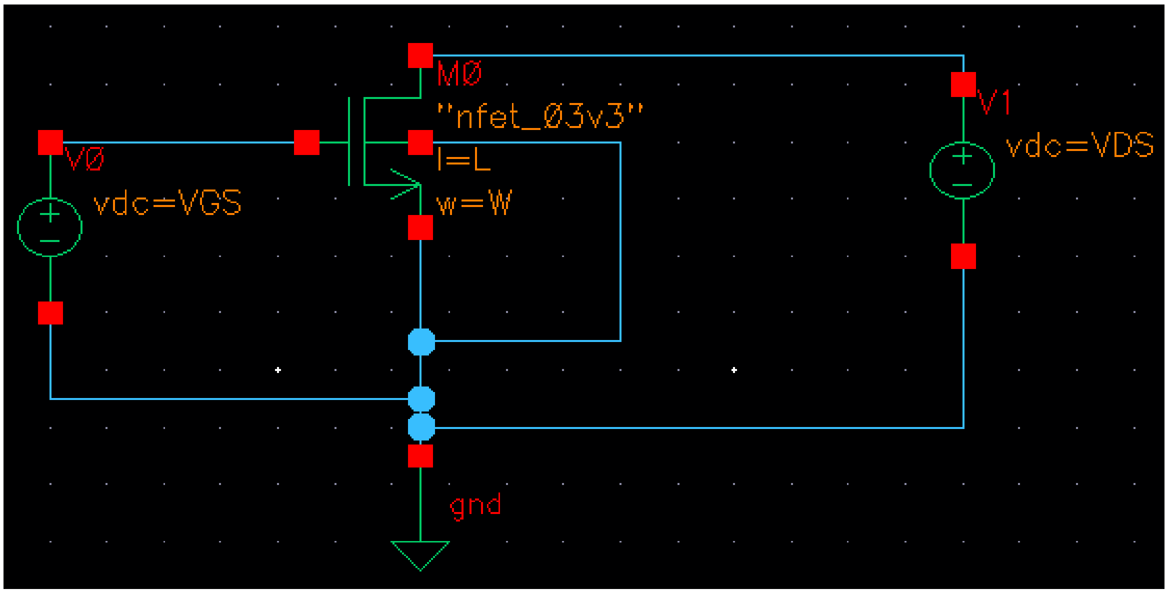

Figure 1: schematic

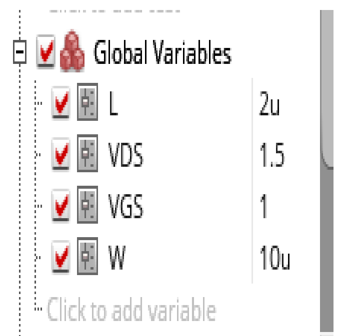

Figure 2: values of Variables

spec	0.18um CMOS
DC Gain	-12
Supply	$3\ V$
Current consumption	$200\ \mu A$

Figure 3: edited spec

Hand analysis:

$$|A_V| = \frac{g_M}{I_D} R_D I_D = \frac{g_m}{I_D} \times \frac{V_{DD}}{2} = 12 \longrightarrow I_D R_D = \frac{V_{DD}}{2} = 1.5 \longrightarrow \text{SO, } R_D = 7.5\ \text{K}\Omega$$

$$V^* = \frac{2 I_D}{g_m} \quad \text{and} \quad |A_V| = \frac{V_{RD}}{V^*} \longrightarrow \text{SO, } V^* = 250\ \text{mV}$$

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(2 * (getData("M0:id" ?result "dc") / getData("M0:gm" ?result "dc")))
```

Figure 4: Expression to calc (V^*)

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(v("M0:vgs" ?result "dc") - v("M0:vth" ?result "dc"))
```

Figure 5: Expression to calc (V_{ov})

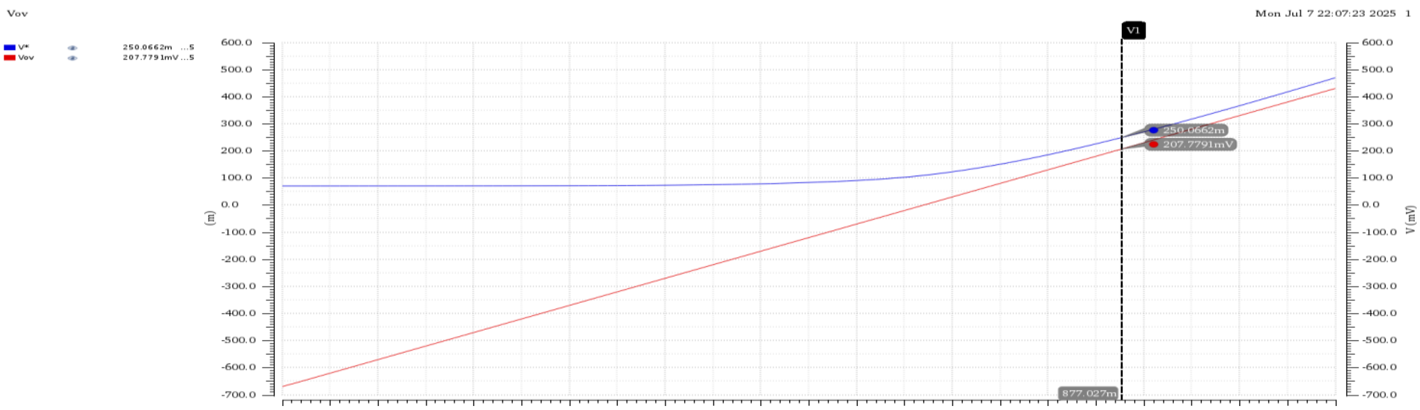

Figure 6: Vov and V* VS Vgs

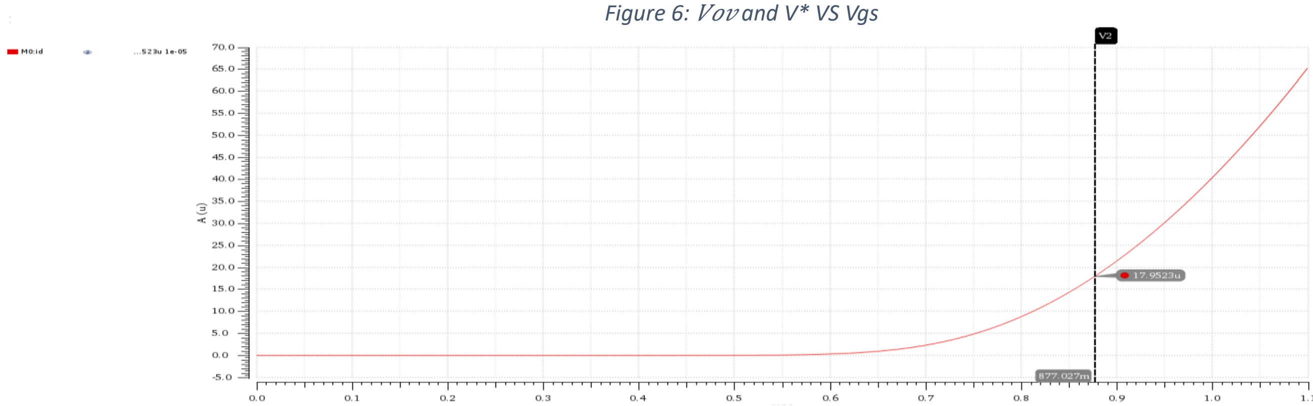

Figure 7: Id VS Vgs

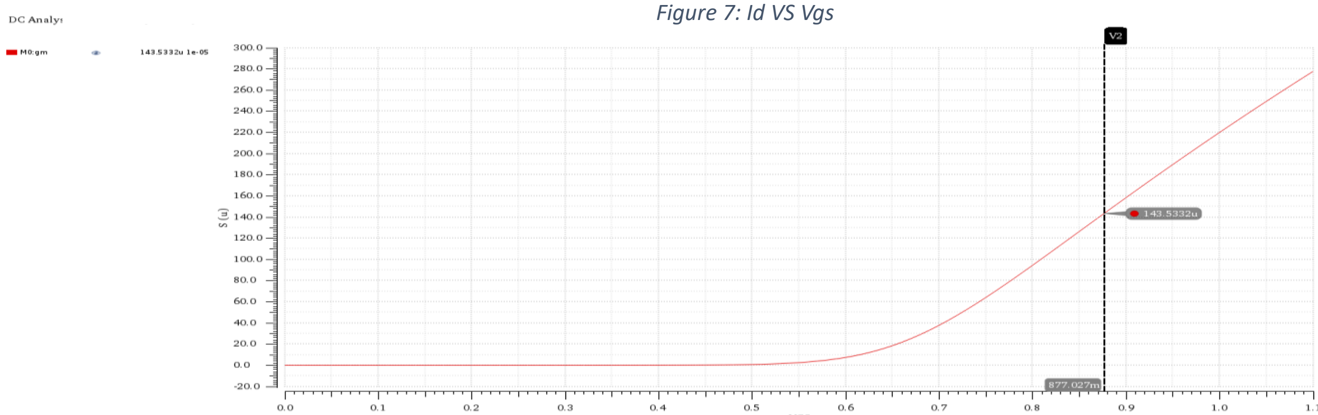

Figure 8: gm VS Vgs

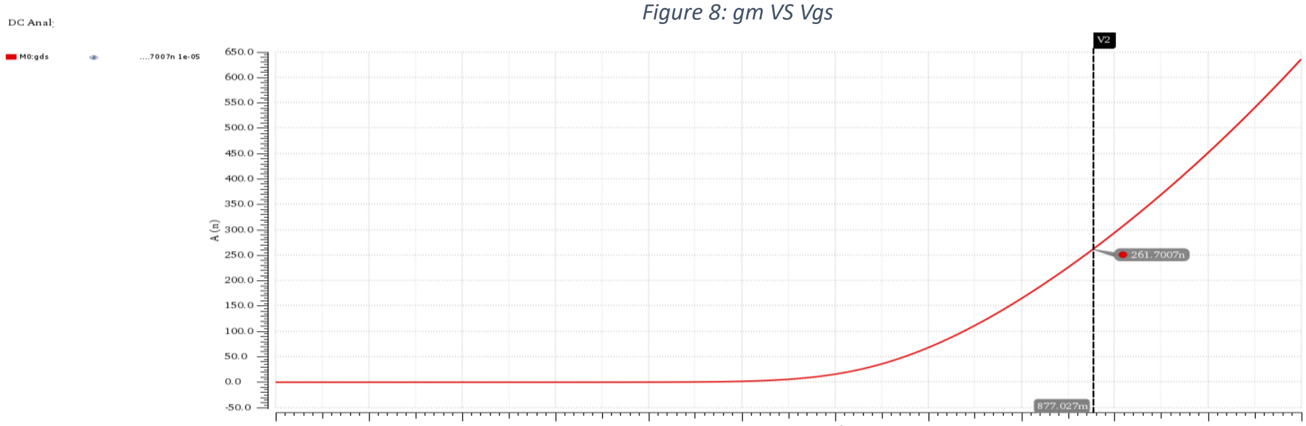

Figure 9: gds VS Vgs

From graphs the required value will be:

1-

V*	**250** mV
R_D	**7.5** KΩ
V_{ovQ}	**207.7791** mV
V_{GSQ}	**877.027** mV
I_{Dx}	**17.9523** μA
g_{mx}	**143.5332** μS
g_{dsx}	**261.7007** nS
Vth	**669 mV**

2-

W	Id
10 μm	**17.9523** μA
111.406 μm	**200** μA

3-

g_m	1.599 mS
g_{ds}	2.9155 μS
r_o	342.9943 KΩ
gain with ro	-11.73588
gain without ro	-11.9925

PART 2: CS Amplifier:

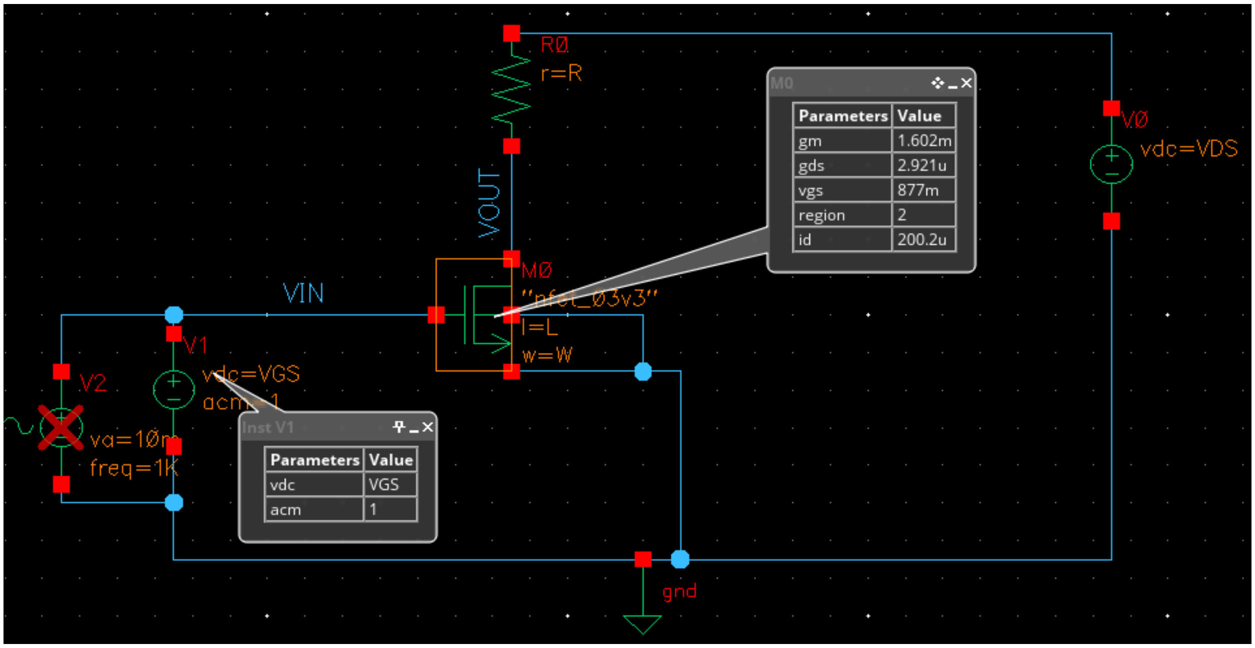

Figure10: schematic

DC OP:

	Values from simulation	Values from part 1
id	200.2 μA	200 μA
gm	1.602mS	1.599 mS
gds	2.921 μS	2.9155 μS
ro	342.3485 KΩ	342.9943 KΩ

Comparison of r_o and RD:

In this case and from shown table, the output resistance r_o is much larger than the drain resistance RD. Since $r_o \gg RD$, its effect on the overall gain is minimal. Therefore, ignoring r_o in the simulation is a valid approximation and does not introduce significant error.

However, if we were to use a minimum-length channel (L = Lmin), the short-channel effects become more pronounced, and r_o decreases significantly. As a result, ignoring r_o in that case could lead to noticeable error in gain calculations. So, the error would not remain the same when using minimum-length devices.

Analytical Calculation of Gain:

| Intrinsic gain| =gm*ro= 548.44 $K\Omega$ - - - - - - - - - - | analytic gain| =gm*Rd=12.02 $K\Omega$

After calculating the analytical gain, we find that it is **much smaller than the intrinsic gain** of the transistor.

This means the relationship is:

Analytical Gain ≪ Intrinsic Gain

The intrinsic gain ($g_m \cdot r_o$) represents the maximum theoretical gain of the device, while the analytical gain is limited by external circuit components such as the drain resistance (RD).

Ask ChatGPT

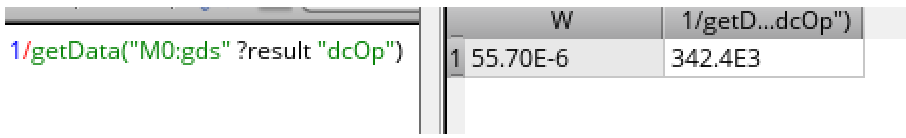

Figure 11: calculate ro from simulation

Ac simulation:

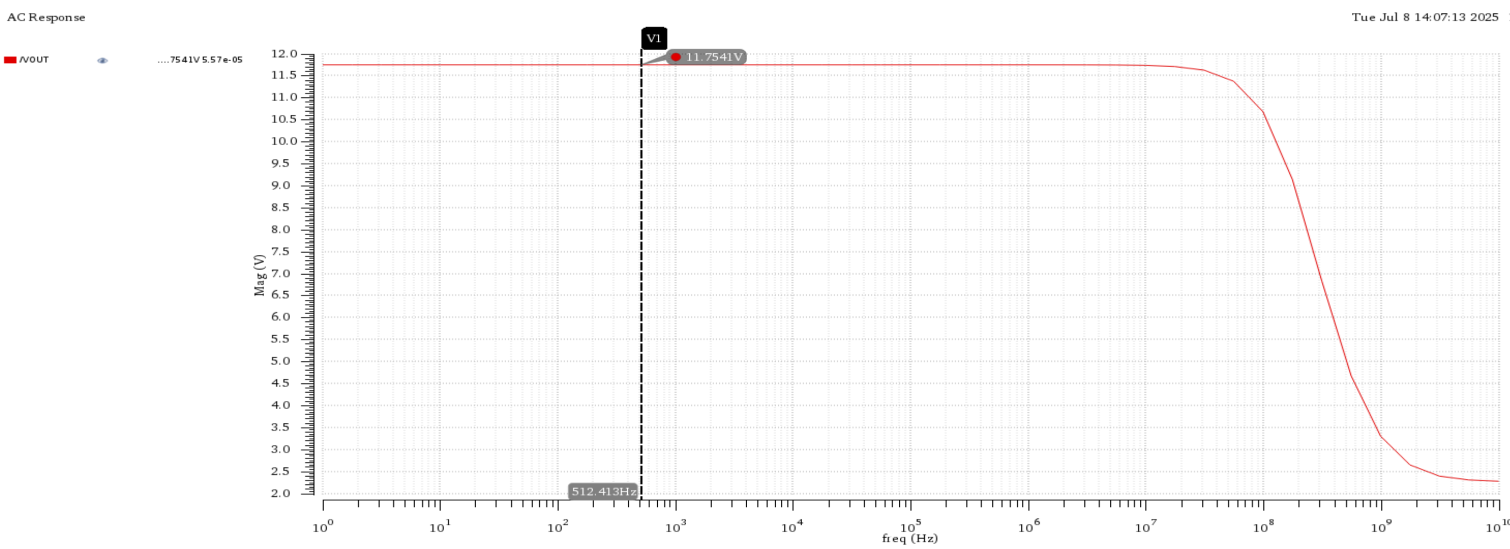

Figure 12: Gain VS freq

Magnitude of DC gain = 11.7541 ≈ 12 V

Our design specification requires a minimum DC gain of approximately 12 V. The obtained result is very close to this target, meaning the design meets the specified gain requirement within acceptable margin and approximately satisfy our specs.

Gain non-linearity:

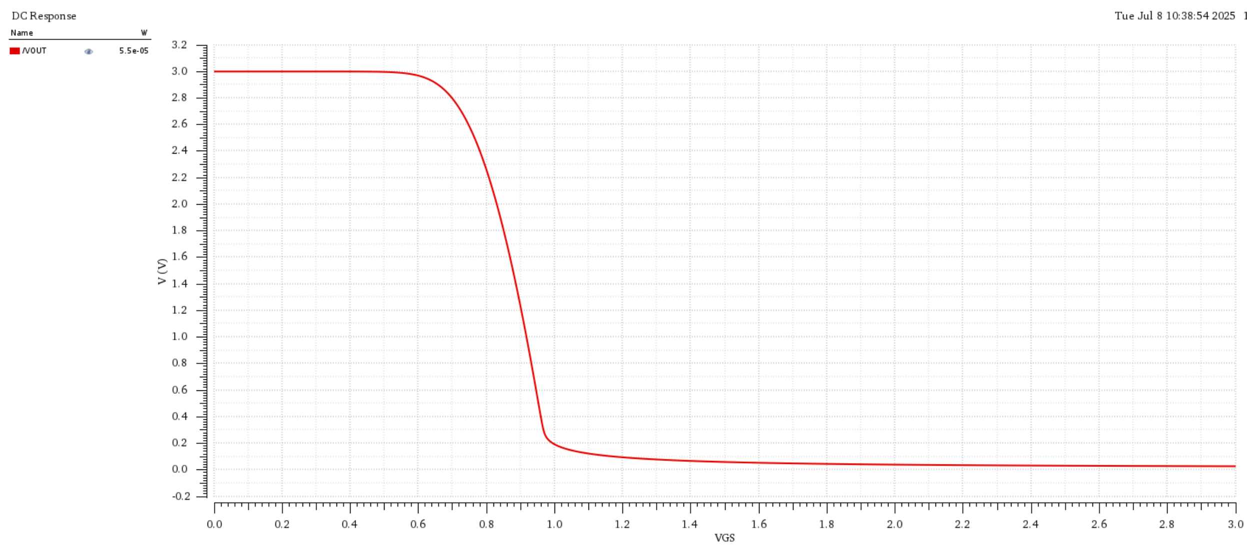

Figure 13: Vout vs Vin

VOUT vs. VIN Report and Linearity:

The relationship between **VOUT and VIN is non-linear** because **VOUT changes significantly at different values of VGS**. As the MOSFET moves through the cutoff, triode, and saturation regions, its behavior changes, causing the output voltage to vary in a non-linear manner with respect to the input voltage.

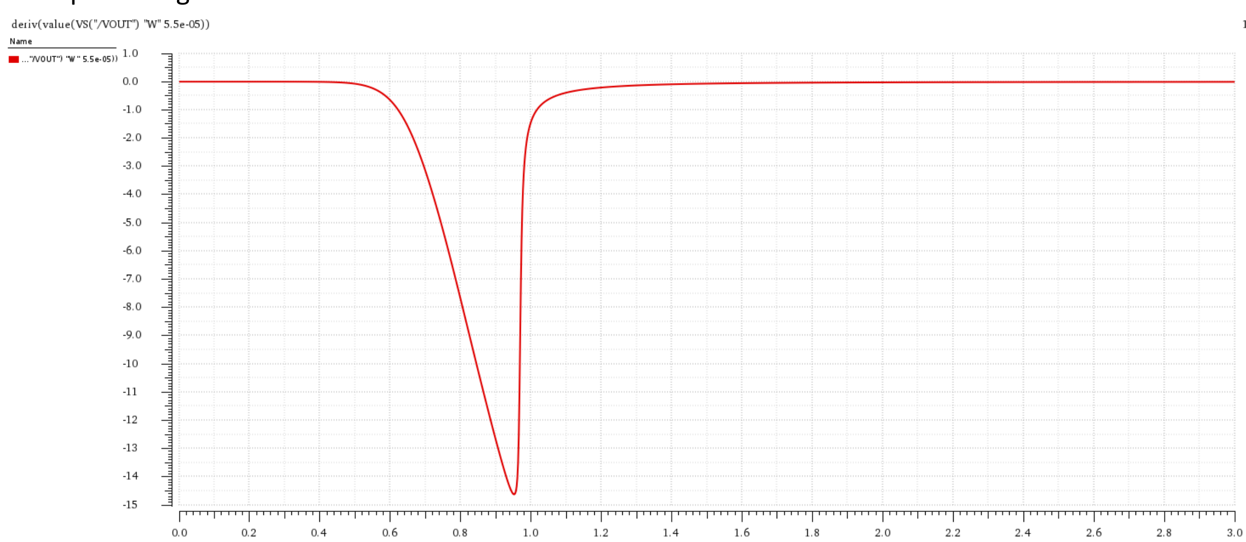

Figure 14: derivative of VOUT

Is the gain linear (independent of the input)? Why?

The gain is **nonlinear**, but at small input voltages (VIN), the gain is approximately linear, though it still depends on VIN to some extent. As the input increases, the transistor transitions through different operating regions, causing the gain to vary and show nonlinear dependence on the input.

Transient analysis :

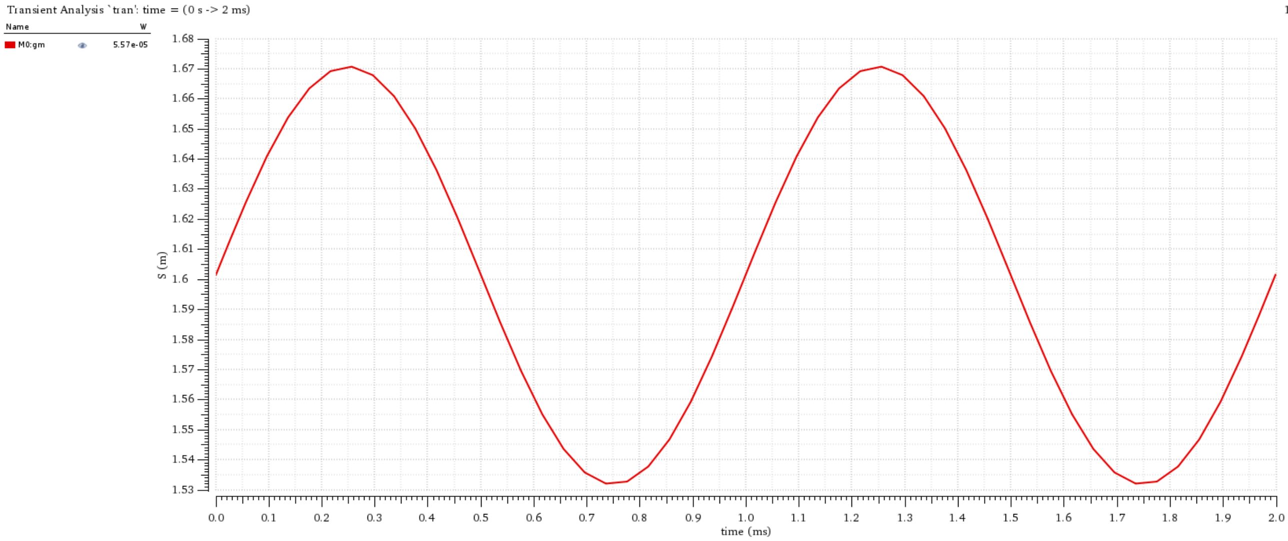

Figure 15:gm VS time

Does gm vary with the input signal?

Based on the time and width (W) data provided, we can infer that gm likely does vary with the input signal since the width values change over time

What does that mean?

The variation in gm with the input signal indicates that the amplifier's transconductance is signal-dependent. This suggests the amplifier is operating in a non-linear region for at least part of the input signal range, as gm would remain constant in a perfectly linear operation.

Is this amplifier linear?

The amplifier appears to be non-linear based on:

- The changing width (W) values over time indicate the operating point is changing with the input signal.
- The variation in gm confirms non-linear behavior