Lab 6 - Common Source Amplifier using NMOS Transistor

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ECE 3110

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1 Introduction and Theory

The circuit that we are analyzing in this lab is shown in Fig. 1. This circuit is an NMOS based common source amplifier, and we are going to design the circuit such that the gain is $A_v = -10$ V/V. We know that $R_L = 10$ kΩ, $R_G = 10$ kΩ, and $R_{\text{sig}} = 50$ Ω, and we want the circuit to have $I_D = 1$ mA. As such, we will need to select the resistors R_S and R_D that meet these conditions. In order to do this, we are going to analyze the circuit in both DC and AC situations.

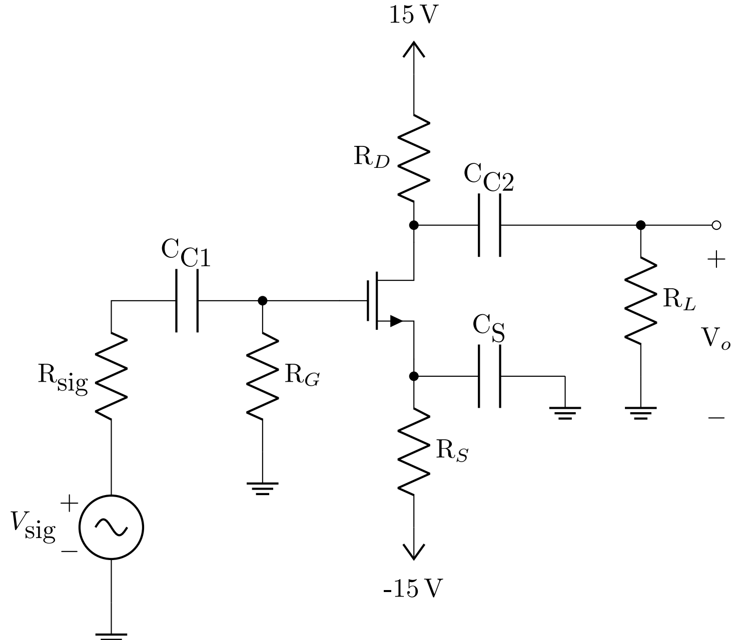

Figure 1: The circuit that we are analyzing in this lab.

2 DC Analysis

In Fig. 2 we can see how the circuit behaves when the considering the DC analysis. Because the capacitors act as open circuits in DC, the circuit is significantly reduced. The DC current through R_G is 0 A.

Using the expression

$$V_{GS} = \sqrt{\frac{2I_D}{k_n}} + V_{th}$$

we can determine that the voltage V_{GS} is $V_{GS} = 2.269$ V.

This yields $V_{ov} = V_{GS} - V_{th} = 0.169$ V.

Also, because V_G is 0 V, we know that $V_S = -V_{GS} = -2.269$ V. Using that value for V_S we can find that $R_S = 12.731$ kΩ.

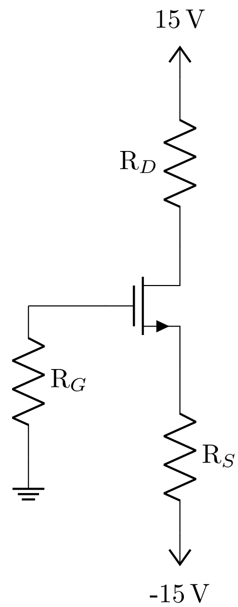

Figure 2: The circuit reduced for DC analysis.

Finishing off the DC analysis we know from the Early voltage that $r_0 = 4165$ V/1 mA = 4.17 MΩ.

3 AC Analysis

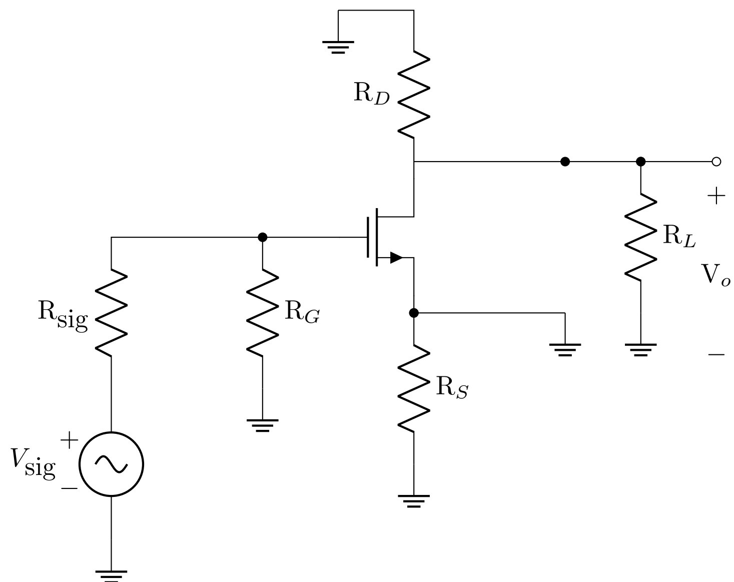

Figure 3: The circuit reduced for AC analysis.

In AC analysis, the sufficiently large capacitors can be replaced with shorts, and the circuit that remains is shown in Fig. 3.

Note as well that the resistor R_S is shorted to ground on both sides and therefore doesn't have an affect on the circuit either. As such the voltage $V_S = 0$ V.

When using the hybrid-π model, we can determine that the voltage $V_o = V_D(r_0 \| R_L)$. This is essentially the same as the expression $A_v = -g_m(R_0 \| R_D)$.

Knowing that $g_m = k_n / V_{ov}$, and $A_v = 10$, we can find that $R_D = 841\Omega$.

This concludes the analysis that we need to do on the circuit, now we can simulate and measure the performance of the circuit.

4 Simulation

When simulating the circuit with Multisim, we found that the gain of the circuit was 9.88 V/V. This is right what we expected from our analysis. You can see the results of the simulation in Fig. 4.

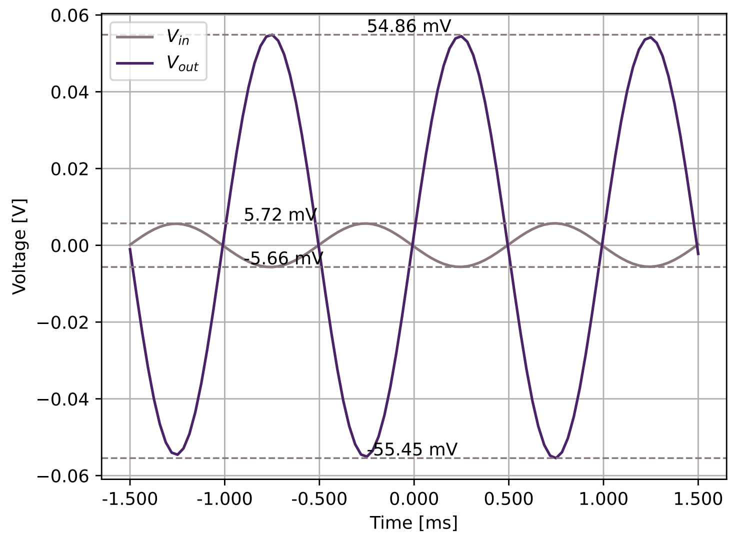

Figure 4: Simulated Circuit Output.

5 Results

When the circuit is built and measured, we find that the value for A_v is $A_v = 6.67\text{V/V}$. This is just a little low, so we increase the resistor R_D until we get about what we want for the gain. We found that using a resistor $R_D \approx 1340\Omega$ yielded about $A_v = 9.46\text{V/V}$ which was just what we wanted. You can see these results in Fig. 5 and Fig. 6.

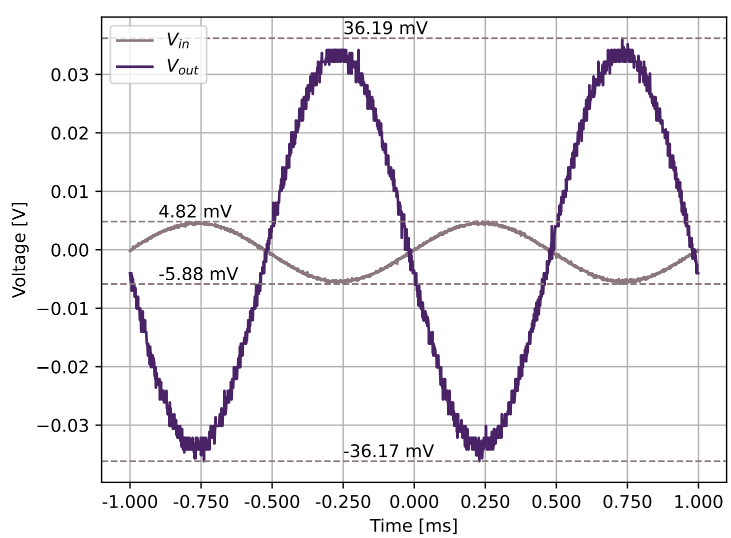

Figure 5: Circuit with 841 Ω. Gain is $A_v = 6.67$.

When placing a 1 MΩ resistor for R_L we found the gain to be about 8, and the gain was halved with R_L was all the way down to just $R_L = 470\ \Omega$.

Table 1 shows the values that were calculated, found equivalently and measured in the experimental portion of the lab.

The output voltage started to rail when the input voltage was increased. There was some distortion around $V_{\text{sig}} =$

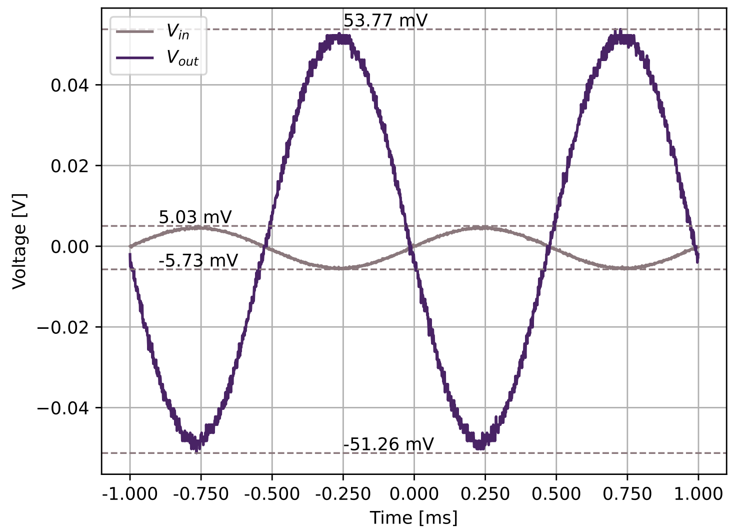

Figure 6: Circuit with 1341 Ω. Gain is $A_v = 9.46$.

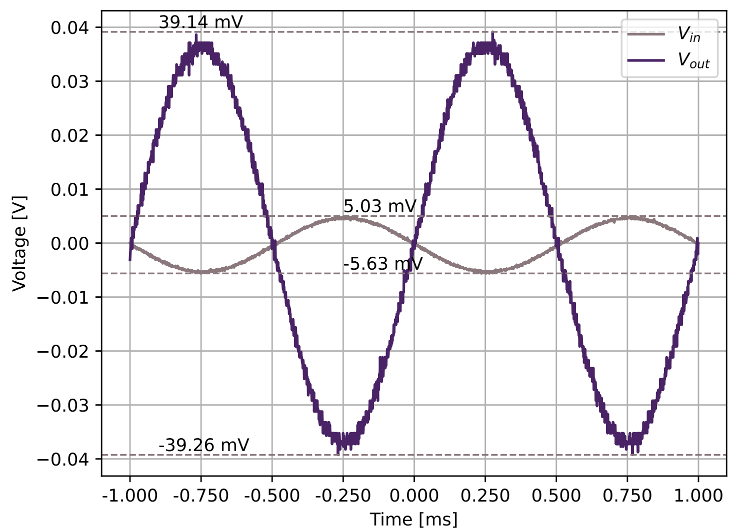

Figure 7: Circuit with 1 MΩ. Gain is $A_v = 8$

250 mV, and extreme distortion as high as $V_{\text{sig}} = 1$ V. This is demonstrated in Figs. 9 and 10.

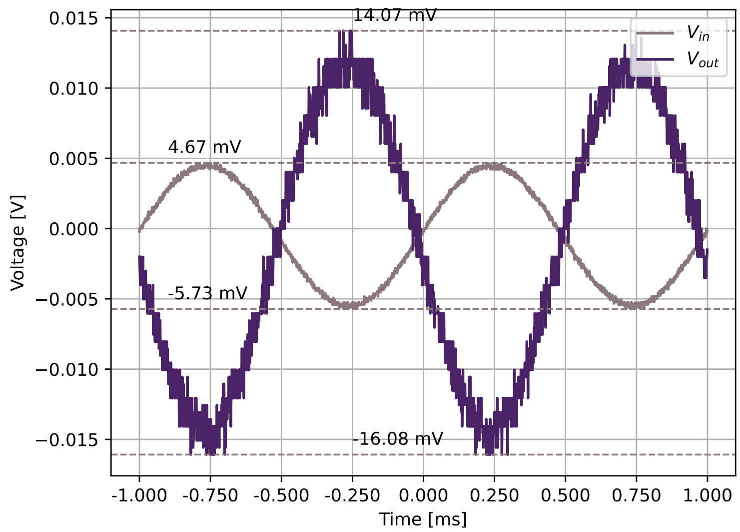

Figure 8: Circuit with 470 Ω. Gain is half of when $R_L = 1$ MΩ.

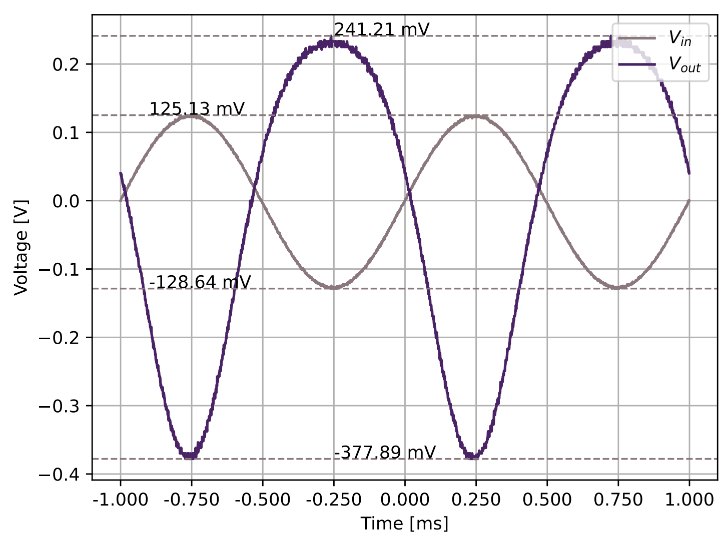

Figure 9: Circuit with input voltage $V_{\mathrm{sig}} \approx 250$ mV.

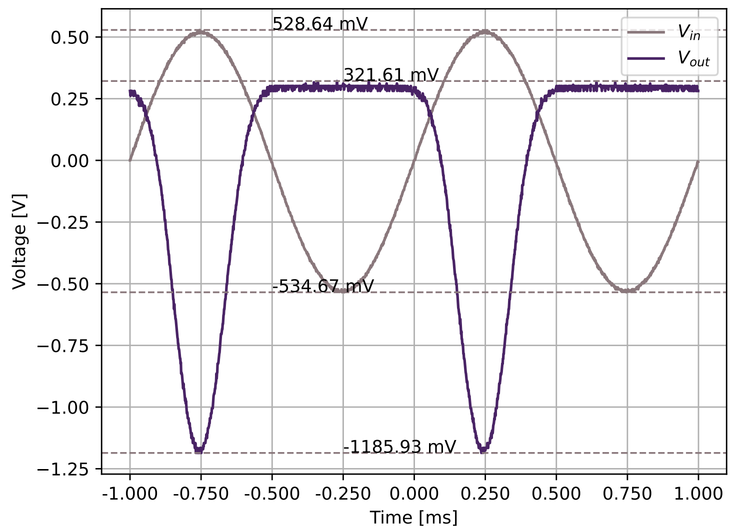

Figure 10: Circuit with input voltage $V_{\text{sig}} \approx 1$ V.

Calculated Resistor	**Equivalent Resistor**	**Measured Resistor**	
12.731 kΩ	12.691 kΩ	12.529 kΩ	R_S
	100 kΩ	99.0 kΩ	
	15 kΩ	14.80 kΩ	
	470 kΩ	464.8 kΩ	
841 Ω	840 Ω	831 Ω	R_D
	10 Ω	9.93 Ω	
	150 Ω	148.6 Ω	
	680 Ω	673.4 Ω	
(1341 Ω)	(470 Ω)	(464 Ω)	
10 kΩ	10 kΩ	9.893 kΩ	R_G
10 kΩ	10 kΩ	9.837 kΩ	R_L
(1 MΩ)	(1 MΩ)	(970 kΩ)	

Table 1: Measured resistors.

6 Conclusion/Post Lab Observations

The driving resistor was the lowest resistor between R_0, R_D, and R_L because of their parallel configuration. The circuit demonstrated that the NMOS transistor can be used as an amplifier, but the output resistance can have an affect on the amplification when below the value for R_D.

With an increasingly high input voltage, the output voltage began to rail, as you can see in Figs. 9 and 10.