Lab 7 - NMOS Based Source Follower

Ty Davis

ECE 3110

November 6, 2024

1 Introduction and Theory

Similar to the last lab, we are going to select resistors to design an amplifier. This time, however, we are designing a *Source Follower* configuration of a MOSFET amplifier. It is also known as the common drain, because the drain lead of the transistor is the common reference for the other leads.

Fig. 1 shows the entire circuit. We are going to design the circuit such that $I_D = 1$ mA and $A_v = 0.8$ V/V. Also, we are given that $R_{\text{sig}} = 50\ \Omega$ and $R_G = 10$ kΩ.

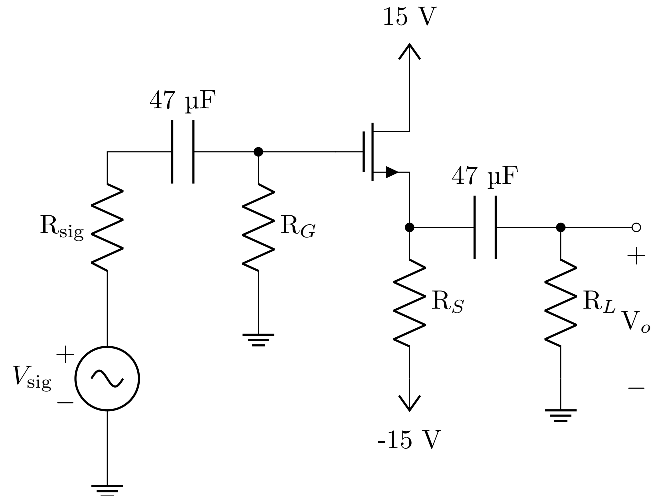

Figure 1: The circuit that we are analyzing in this lab.

2 DC Analysis

To start off, we need to find the correct value of R_S to bias the transistor properly. For DC analysis, we can assume that the capacitors act as open circuits, and the remaining circuit is shown in Fig. 2.

Knowing that $I_D = 1$ mA, and using this equation:

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

we can obtain a value for V_{GS}. Remember from the previous labs that $k_n = 70.3$ mA/V^2, and $V_{th} = 2.1$ V. This yields $V_{GS} = 2.269$ V.

Without out any current flowing through the gate of the transistor, the voltage $V_G = 0$ V, and thus $R_S = 12.731$ kΩ. It's good to note right now as well that $V_{ov} = 0.169$ V.

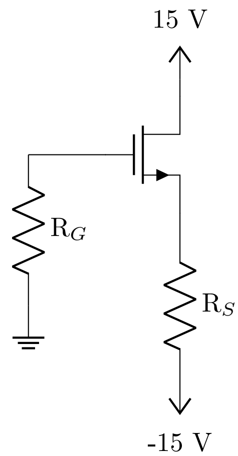

Figure 2: The circuit after removing the capacitors.

3 AC Analysis

Fig. 3 shows the circuit as it can be used for the AC analysis. The transistor has been replaced by the *T Model*, and the capacitors have all been swapped for short circuits.

Seeing the circuit this way can help for small signal analysis. We are designing the circuit such that $A_v = 0.8$ V/V, and we know that $A_v = \frac{v_o}{v_i}$. Looking at the circuit with the T Model we can see derive the following voltage divider:

$$v_o = v_i \frac{R_L \| R_S}{1/g_m + R_L \| R_S}$$

Using $g_m = k_n V_{ov}$, we find $g_m = 11.8\ \mathrm{m\,S}$, which allows us to find $R_L \| R_S = 336.68\ \Omega$.

With the calculated R_S from the DC analysis, R_L is then equal to $R_L = 345.8\ \Omega$.

The output R_o looking into the amplifier is clearly shown with the T Model, and is simply just $R_o = 1/g_m$.

It's good to note as well, that the ratio of R_G to R_{sig} is so large that you can essentially approximate $v_i = v_{\text{sig}}$.

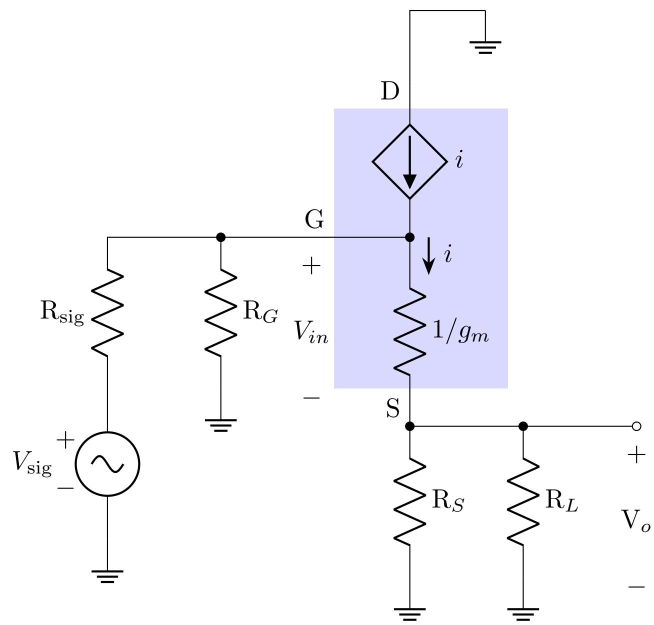

Figure 3: The T Model equivalent circuit with capacitors replaced by shorts.

4 Simulation

Simulating the circuit with Multisim was straightforward, and the results are shown in Fig. 4. The gain was simulated at $A_v = 0.82$ V/V.

The DC operating points were: $V_G = 450$ nV, $V_{GS} = 2.13$ V, $V_{DS} = 17.14$ V, and $I_D = 0.997$ mA.

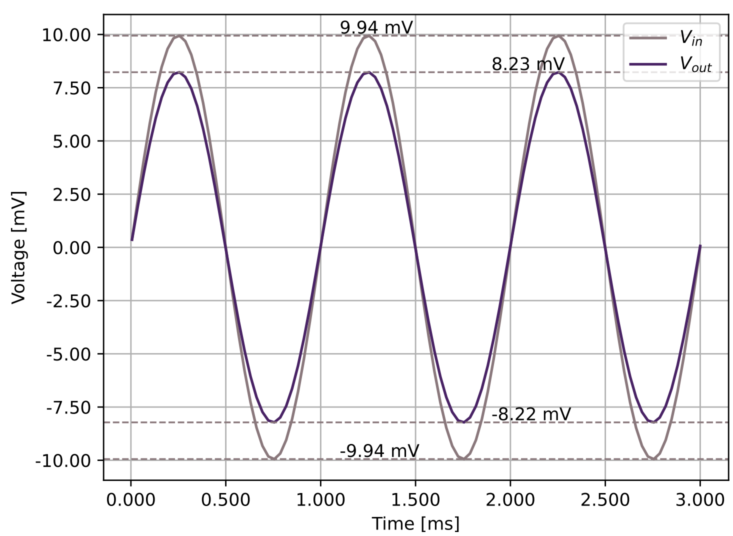

Figure 4: Simulation Results.

5 Results

Building and Measuring the circuit showed that our calculations and simulation were accurate.

The DC operating points were found at $V_G = 0$ V, $V_{GS} = -1.89$ V, $V_{DS} = 16.89$ V, and $I_D = 1.04$ mA was calculated from the corresponding values and the measured resistance. All the measured resistors are shown in Table 1.

Fig. 5 shows the input vs output waveform, and the measured gain was $A_v = 0.748$ V/V.

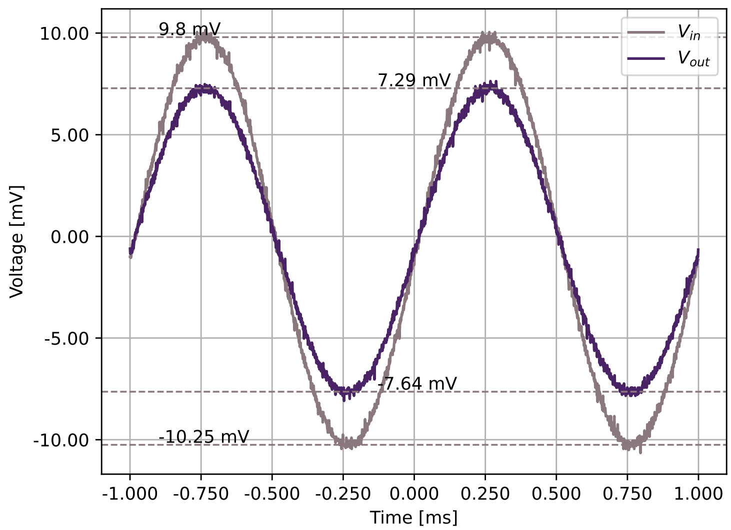

Figure 5: Measurement Results.

Calculated Resistor	Equivalent Resistor	Measured Resistor	
12.731 kΩ	12.691 kΩ	12.517 kΩ	R_S
	100 kΩ	98.8 kΩ	
	15 kΩ	14.79 kΩ	
	470 kΩ	464.1 kΩ	
345 Ω	340 Ω	334 Ω	R_D
	10 Ω	9.84 Ω	
	330 Ω	324 Ω	
10 kΩ	10 kΩ	9.86 kΩ	R_G

Table 1: Measured resistors.

6 Post-Measurement Exercise

Some of the answers were included in the **Results** section, but the remaining questions are answered here.

Q. What would happen if you used the function generator with 50Ω output resistance to directly drive your load resistor?

A. Without the buffer amplifier, the output signal would be attenuated to according to the voltage divider with the signal resistance and the 340 Ω load resistance. The corresponding gain would be about $A_v = 0.87$. That's comparable to our circuit.

Q. What would happen if the output resistance of the function generation was changed from 50 Ω to 5 kΩ?

A. With a much larger input resistance, the signal is significantly attenuated according to a much more extreme voltage divider. The resulting gain would be $A_v = 0.064$, which is very poor. Using the buffer circuit prevents this.