Lab Report 8 by Jamie O'Brien, Sabrina Pereira, and Shyheim Russell

1 Introduction

The purpose of this lab is to become familiar with the differential amplifier and its characteristics, and consists of three experiments. In the first experiment, we will be examining the behavior of the differential amplifier in response to changes in the common-mode input voltage and the differential-mode input voltage. In the second experiment, we will measure the incremental output resistance of the differential amplifier and its incremental transconductance gain. In the third experiment, we will examine the voltage transfer characteristics of the amplifier configured as a unity-gain follower. For all three experiments, we will be constructing circuits using ALD1106 quad nMOS transistors and ALD1107 quad pMOS transistors, and we will be taking measurements using a source-measurement unit (SMU).

2 Experiment 1: Voltage Transfer Characteristics

In this experiment, we constructed a differential amplifier that consists of an nMOS differential pair and a pMOS current mirror. We set the bias voltage, $V_b = .7$V to keep the bias current, I_b, just at threshold. We connected V_2 to a voltage source and swept V_1 from one rail to the other, and measured V_{out}. We did this for three different values of V_2 that are above V_b : $V_2 = 2V, 3V, 4V$. The results of these measurements are shown in Figure 1.

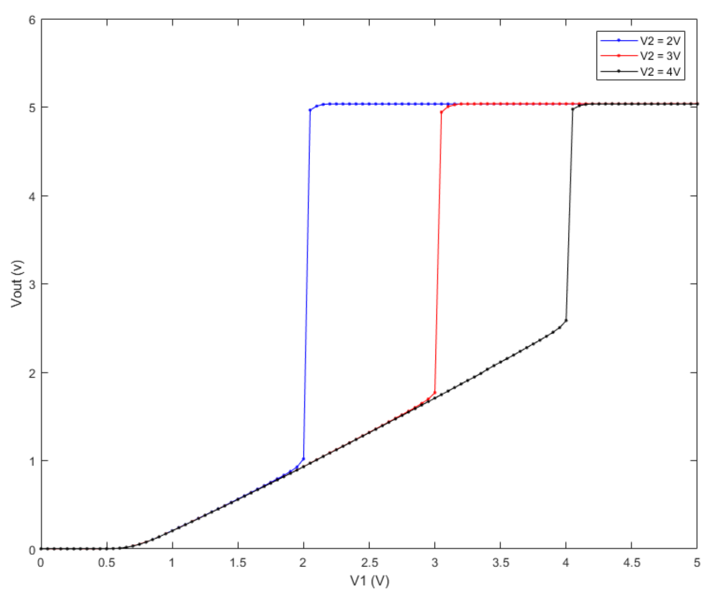

Figure 1: V_{out} vs. V_1 for three values of V_2 with I_b at threshold.

We then repeated this experiment for an above-threshold I_b, with $V_B = 1.5V$. As seen in Figure 2. The behavior of the circuit looks similar when biased in strong inversion compared to that which it exhibits in weak/moderate inversion. In weak/moderate inversion, the graphs are much sharper between the transition around where $V_1 = V_2$ than the strong inversion graphs are.

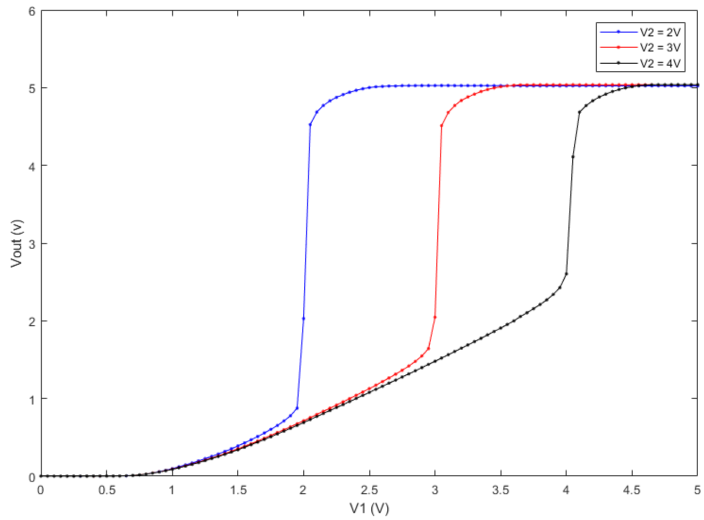

Figure 2: V_{out} vs. V_1 for three values of V_2 with I_b above threshold.

3 Experiment 2: Transconductance, Output Resistance, and Gain

In this experiment, we chose a single value of $V_2 = 2V$ and swept V_1 around V_2 in fine increments and measured V_{out}. In Figure 3, we see that the voltage transfer characteristic is linear around $V_1 - V_2$ and the slope of the linear fit is the differential-mode voltage gain, A_{dm}, which can be found as

$$A_{dm} = \frac{\partial V_{out}}{\partial V_{dm}} = \frac{\partial V_{out}}{\partial I_{out}} * \frac{\partial I_{out}}{\partial V_{dm}} = R_{out} * G_m \tag{1}$$

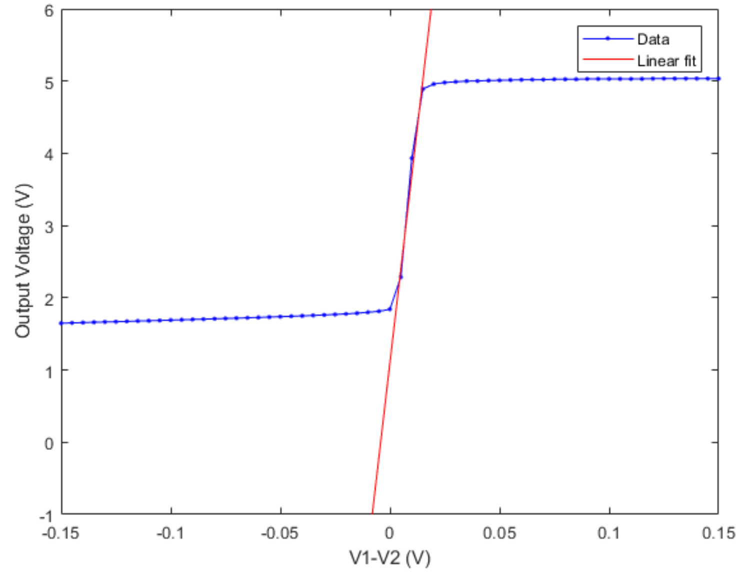

Figure 3: V_{out} vs. $V_1 - V_2$ for fixed V_2.

From the slope of the VTC, we get that $A_{dm} = 260.47$.

Figure 5 shows V_{out} as a function of V_{dm}, as $V_{dm} = V_1 - V_2$. Next, we set V_{dm} to 0 and measured the output current, I_{out}, while we swept V_{out} from one rail to the other. The slope of the linear fit in Figure 4 tells us the incremental output resistance, R_{out}. From this we extracted that $R_{out} = 2.1e + 07\ \Omega$.

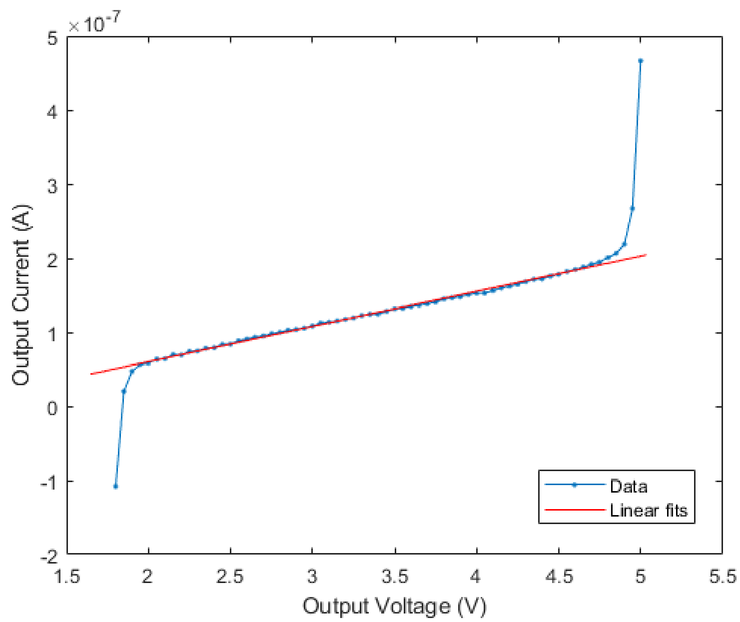

Figure 4: I_{out} vs. V_{out}.

Finally, we fixed V_{out} in the middle of the range of output voltages for which the circuit's gain is large, so $V_{out} = 3V$. We measured I_{out} as we swept V_1 around V_2. The slope of the linear best fit line in Figure 5 tells us the incremental transconductance gain of about $3.56e-4$ Mhos.

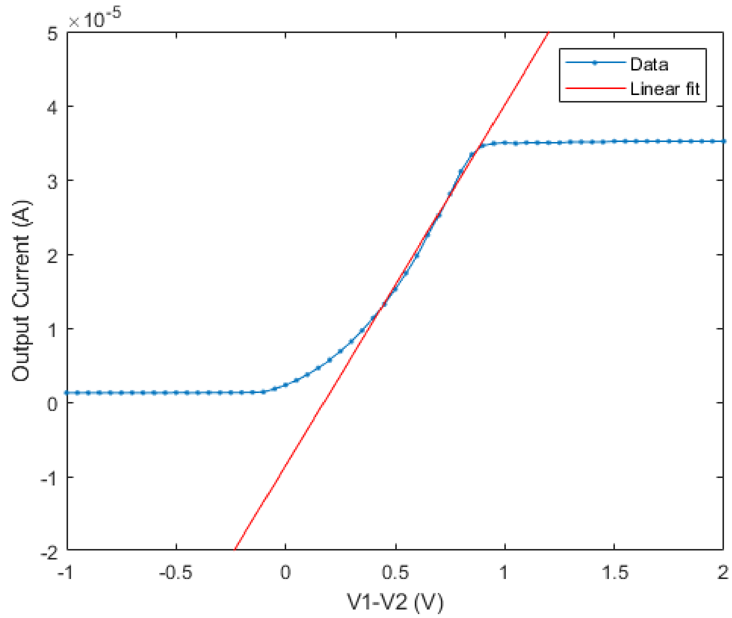

Figure 5: I_{out} vs. V_{dm}.

From the equation, $A_{dm} = R_{out} * G_m = 7.49\text{e}+03$. This is quite different for the calculated. From comparing to the values of other teams, it seems that our calculated value for R_{out} was too high, so this may be due to errors in data collection.

4 Experiment 3: Unity-Gain Follower

In this experiment, we configured out amplifier as a unity-gain follower by connecting the output to the inverting input terminal. We swept V_{in} from one rail to the other and measured V_{out}. The the slope of the linear best fit line of the voltage-transfer characteristic, shown in Figure 6, tells us the incremental gain, which we calculated to be is 1.004, very close to unity.

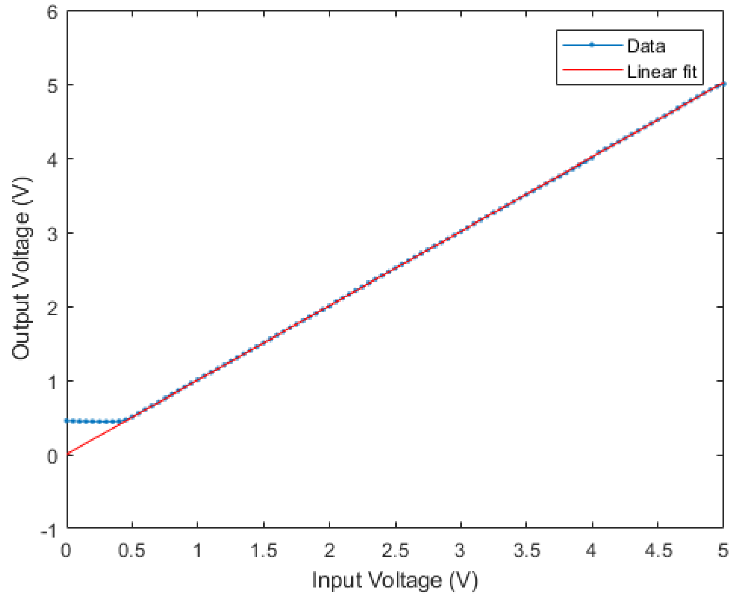

Figure 6: V_{out} vs. V_{in} for

We repeated the sweep of V_{in} and measured $V_{out} - V_{in}$ directly. The plot of $V_{out} - V_{in}$ versus V_{in}, shown in Figure 7, represents the offset voltage of the amplifier. As V_{in} changes, the offset voltage decreases at a slow rate from up until V_in is greater than 4.5V where it starts to decrease by a faster rate.

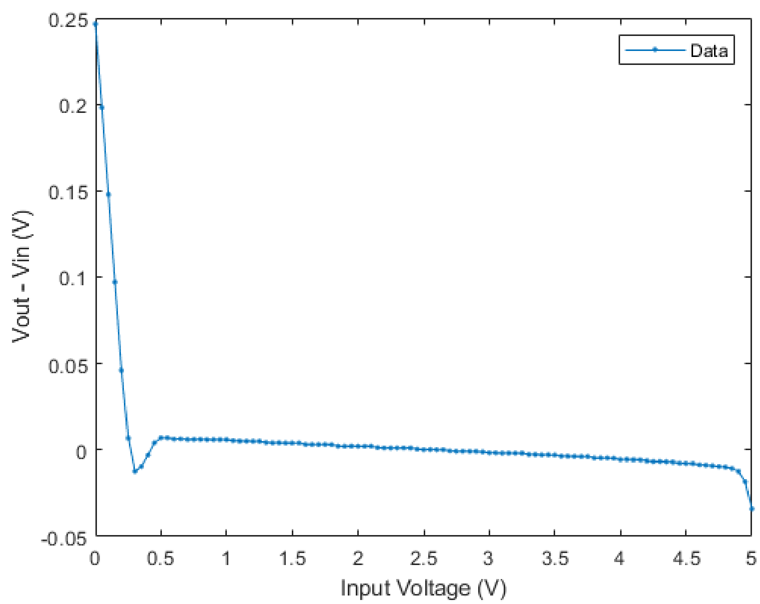

Figure 7: $V_{out} - V_{in}$ vs. V_{in}.