Lab 9: A Current - Mirror Differential Amplifier

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Experiment 1: Voltage Transfer Characteristics

In this experiment, we constructed a current-mirror differential amplifier using an nMOS differential pair, two pMOS current mirrors, and one nMOS current mirror. We set the bias voltage to 1V of the nMOS differential pair such that the bias current is very small (micro amps) which results in moderate inversion.

We know that V1 is the noninverting input and V2 is the inverting input. We measured Vout as a function of the noninverting input for a few constant values of V2.

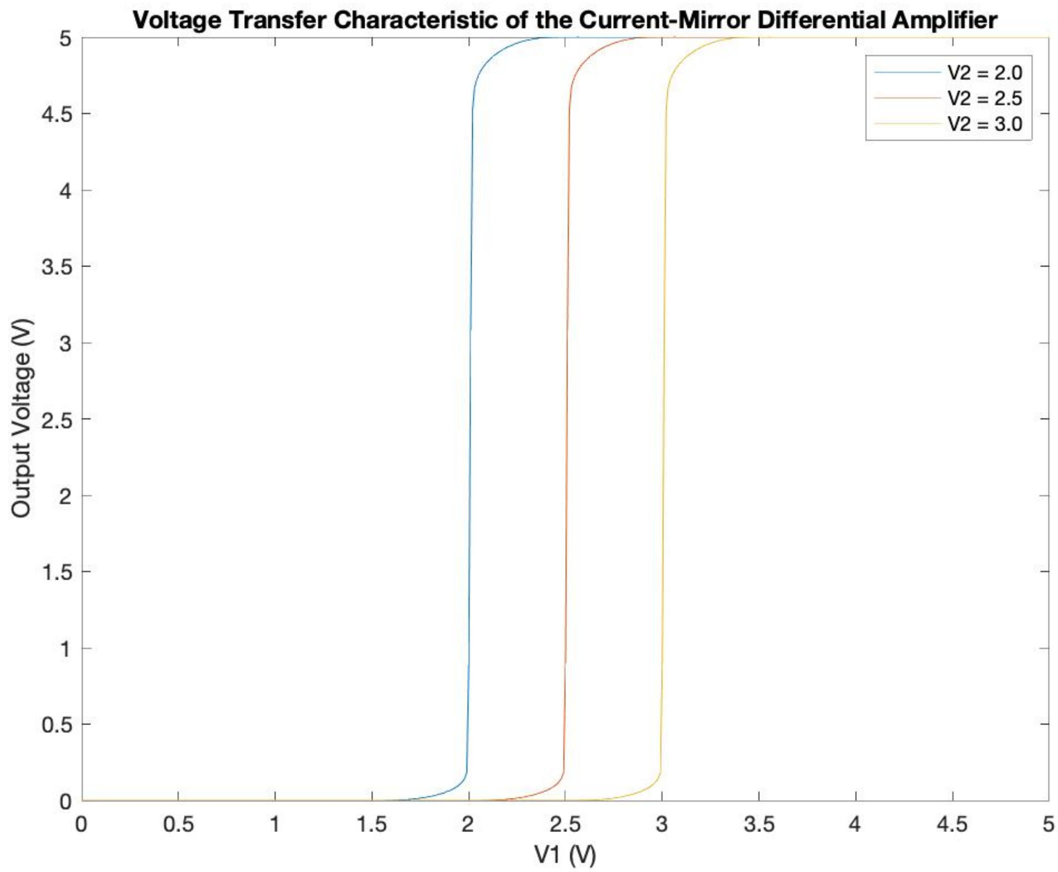

Figure 1: Voltage transfer characteristic of the current-mirror differential amplifier.

This amplifier spends the majority of the time at either rail. It virtually takes no time to transition between the two. On the other hand, the simple differential amplifier in lab 8 took much longer to transition between ground and the Vdd.

Experiment 2: Transconductance, Output Resistance, and Gain

In this experiment, we looked at the voltage transfer characteristic of the circuit in small increments around a few values of V2. Then, we measured the current flowing into the amplifier as a function of Vout with Vdm equaling 0 (V1 = V2). Lastly, we measured the current flowing out of the amplifier as a function of the differential-mode voltage with the Vout held at a value which kept the gain high.

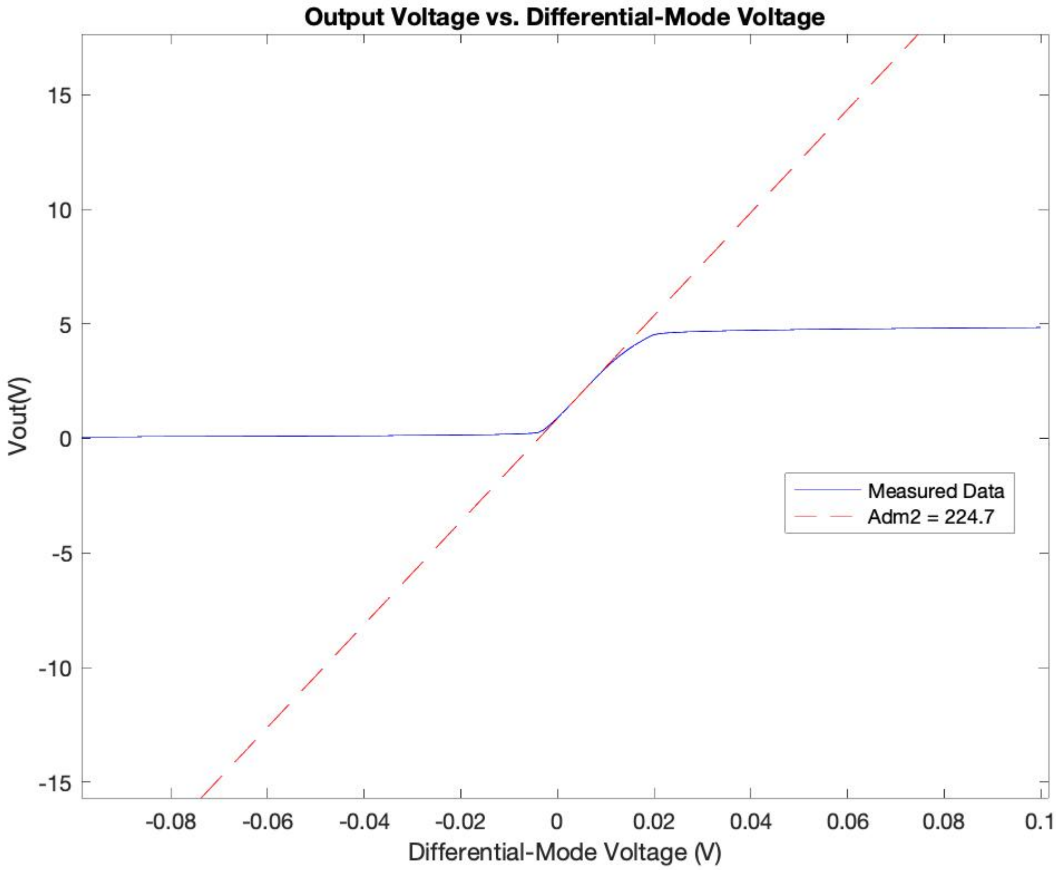

Figure 2: Output voltage as a function of the the differential-mode voltage.

From figure 2, we were able to find the differential mode voltage gain for the circuit which we found to be 224.7.

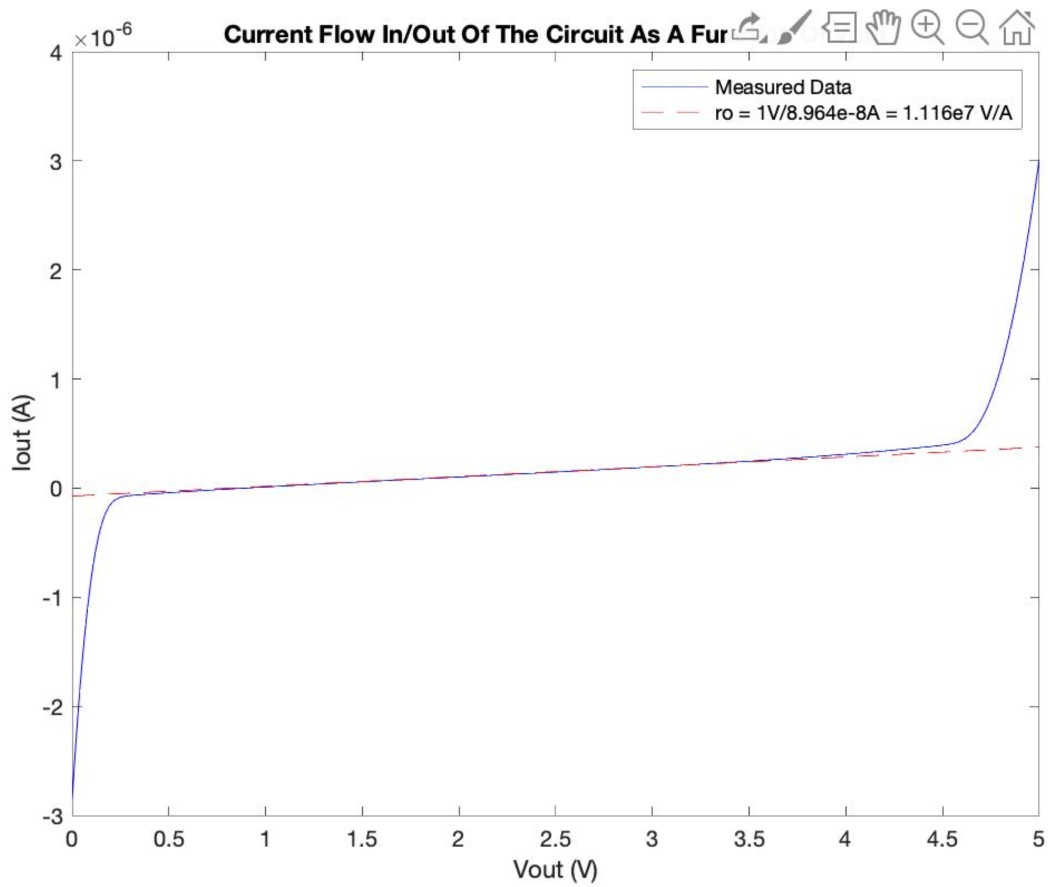

Figure 3: How the current flow changes depending on Vout if V1 and V2 don't impact it.

The incremental output resistance is 1.116e7 Ohms which we found by taking the inverse of the slope of the linear region of figure 2.

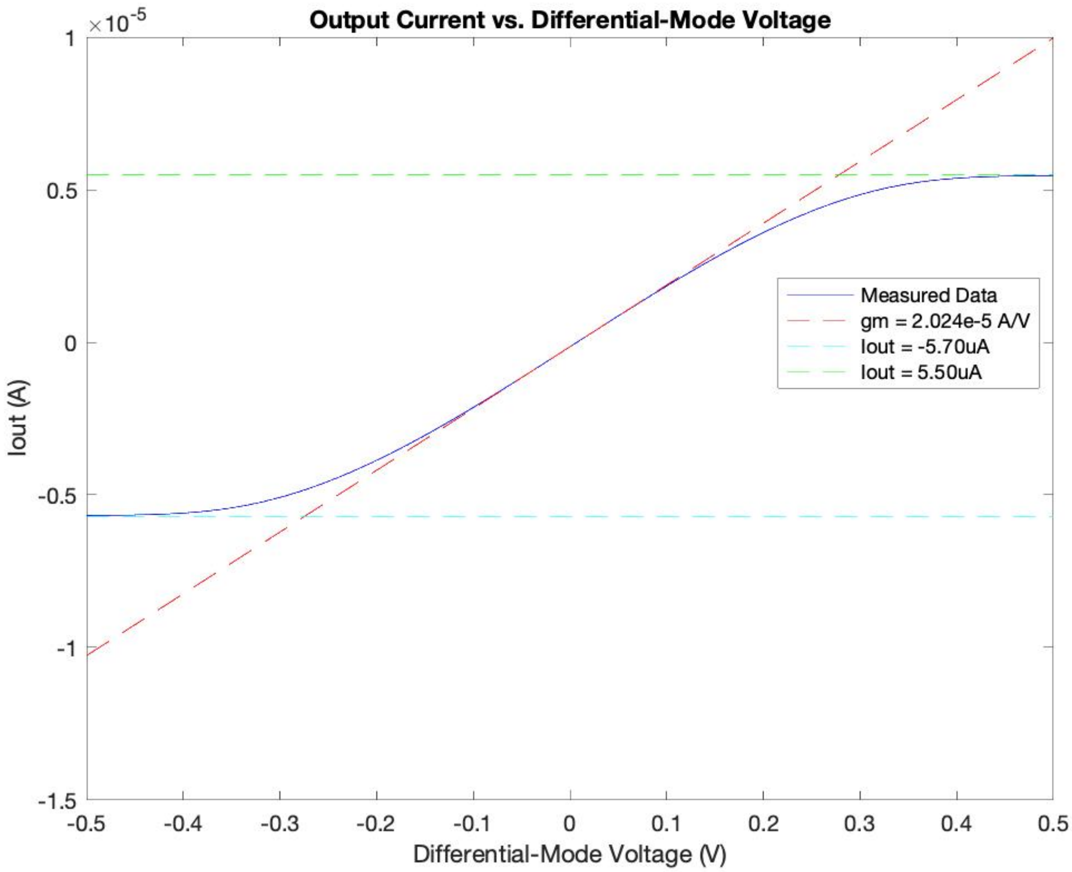

Figure 4: Output voltage as a function of the differential-mode gain.

We can solve for the differential mode voltage gain by the following equation.

$$A_{dm} = r0 * gm$$

From this, we can find that the extracted Adm is 225.8784.

The error between the extracted Vdm (experimental) and the Vdm found through is slope (theoretical) is .52%.

The differential-mode gain of the simpler differential amplifier was 256.88 in weak inversion. The differential-mode gain of this differential amplifier was 225.88 in moderate inversion. They are both relatively similar to each other. We can also expect the Adm for the simpler differential amplifier to reduce when in moderate inversion which will bring the number closer to what we have in the moderate inversion for this amplifier.

Experiment 3: Unity-Gain Follower Step Response

In this experiment, we configured the amplifier as a unity-gain follower by connecting the output to the inverting input. Between the output of the amplifier and ground, we also put a 1 nF capacitor. We then applied a small-amplitude square wave to the input of the circuit and watched the input and output square waves of the circuit. Next, we repeated this process for a large amplitude square wave. For the small amplitude, we used an amplitude of 0.1 V. For the large amplitude square wave, we used an amplitude of 2V.

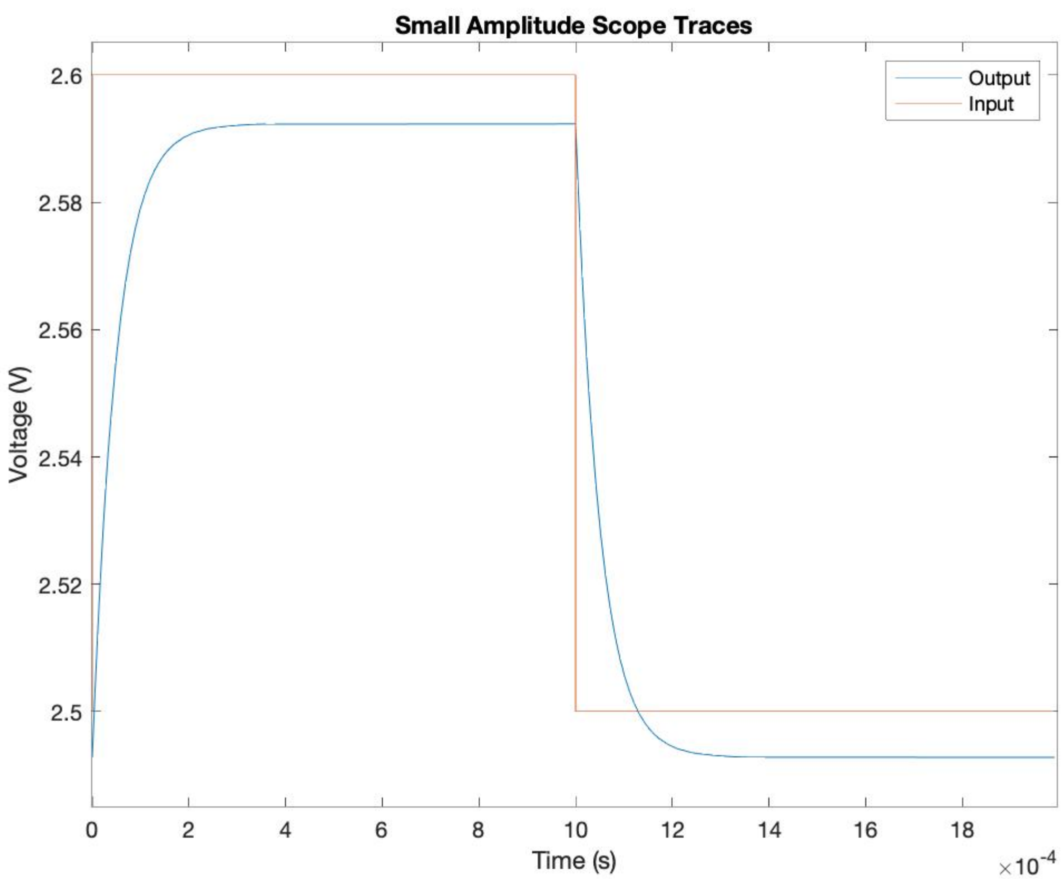

Figure 5: Scope traces of the small amplitude input and output voltages.

We also know that the upward time constant is 4.941e-5 seconds and the downward time constant is 4.907e-5 seconds. The response is almost symmetrical. The reason why it is not symmetrical is that the capacitor charging and discharging causes lags. The amplifier does exhibit approximately linear behavior.

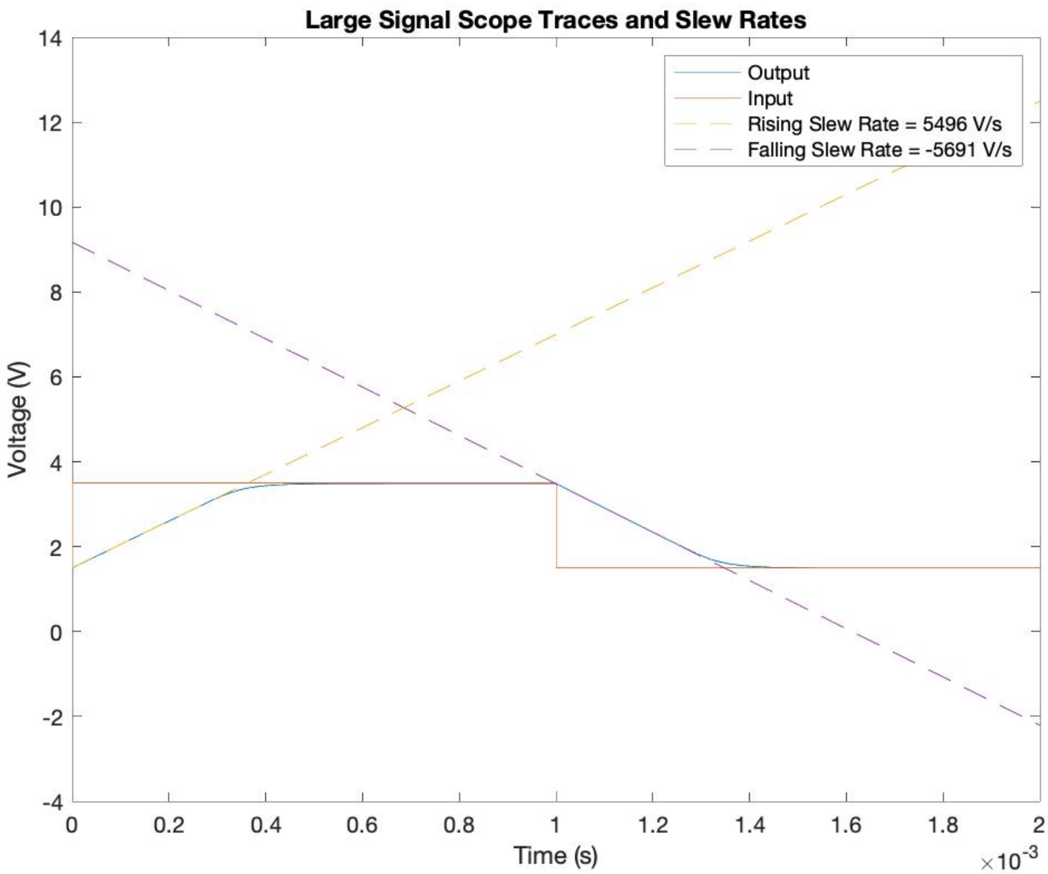

Figure 6: Scope traces of the large amplitude input and output voltages.

From figure 6, we know that the rising slew rate is 5496 V/s and the falling slew rate is -5691 V/s. These are not symmetric and therefore we know that the response to the large amplitude signal is not symmetric.

The calculated slew rate is 5.5uA/1nF = 5,500 V/S. All of our slew rates from figure 6 are around the maximum slew rate.