Lab 8: A Simple MOS Differential Amplifier

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Experiment 1: Voltage Transfer Characteristics

In this experiment, we constructed a differential amplifier with an nMOS differential pair and a pMOS current mirror. We set the bias voltage such that the bias current was at threshold. We measured Vout as a function of V1 or the non-inverting input voltage (swept from one rail to the other) for 3 different V2 values that are all above the bias voltage. We then repeated this process with a bias voltage such that the bias current was above threshold.

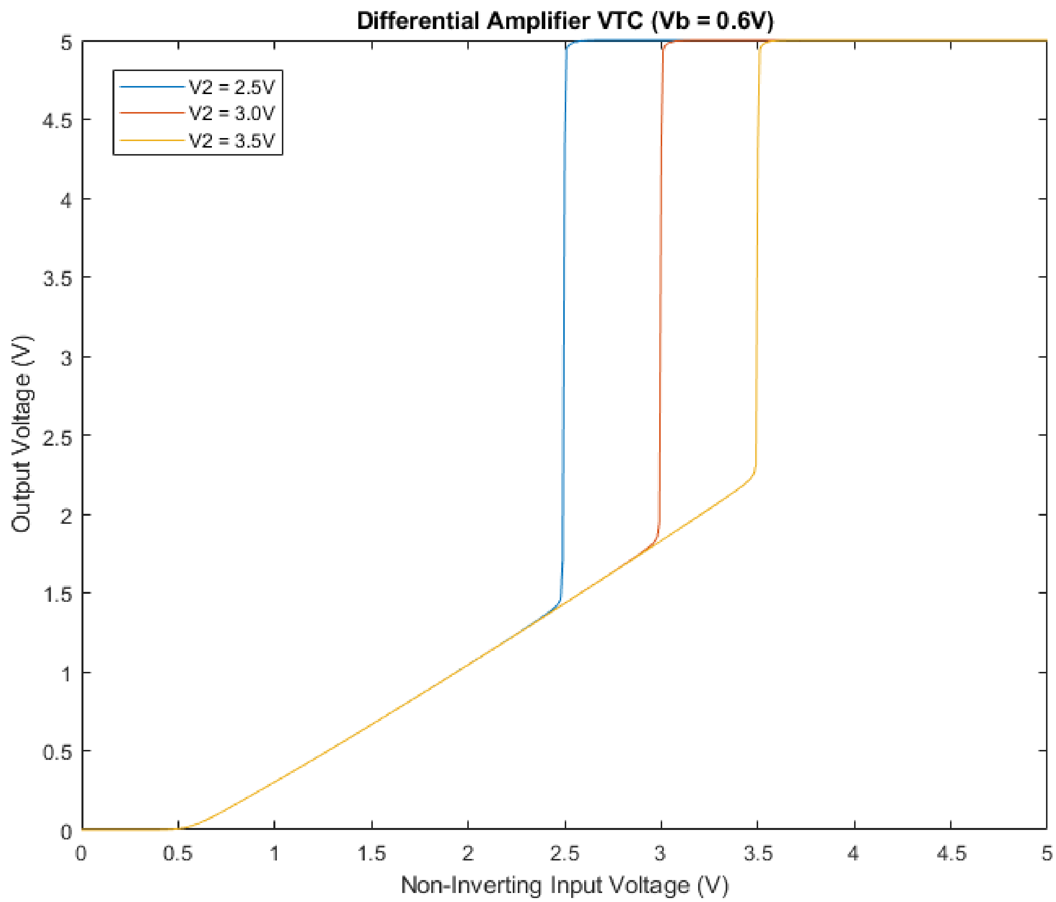

Figure 1: Voltage transfer characteristic of a differential amplifier with the bias voltage at threshold.

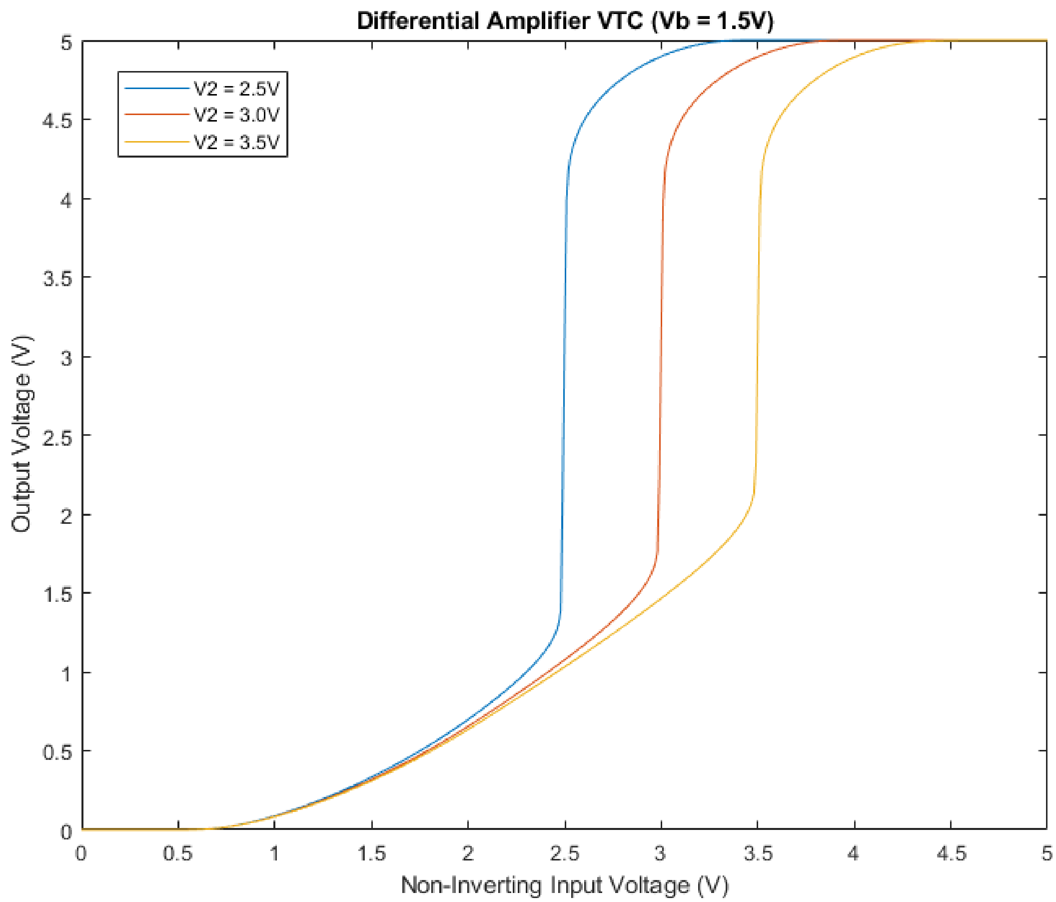

Figure 2: Voltage transfer characteristic with the bias voltage above threshold.

The pattern found in the voltage transfer characteristics for both of the bias voltage values is very similar. There is an initial period where there is a steady increase at the lower V1 values. Then, there is a sudden increase in the output voltage at both bias voltages when the non-inverting input voltage equals the V2 value that was set. Lastly, all of the output voltages rail at 5V.

The only difference in the behavior between the weak or moderate inversion and the strong inversion biases is that the transitions between these three stages of behavior are more gradual in the strong inversion. This is a similar trend that we saw in lab 7. When biased in strong inversion, the output voltages take longer to change.

Experiment 2: Transconductance, Output Resistance, and Gain

In this experiment, we measured Vout as a function of V1 which was swept around V2 in high resolution.

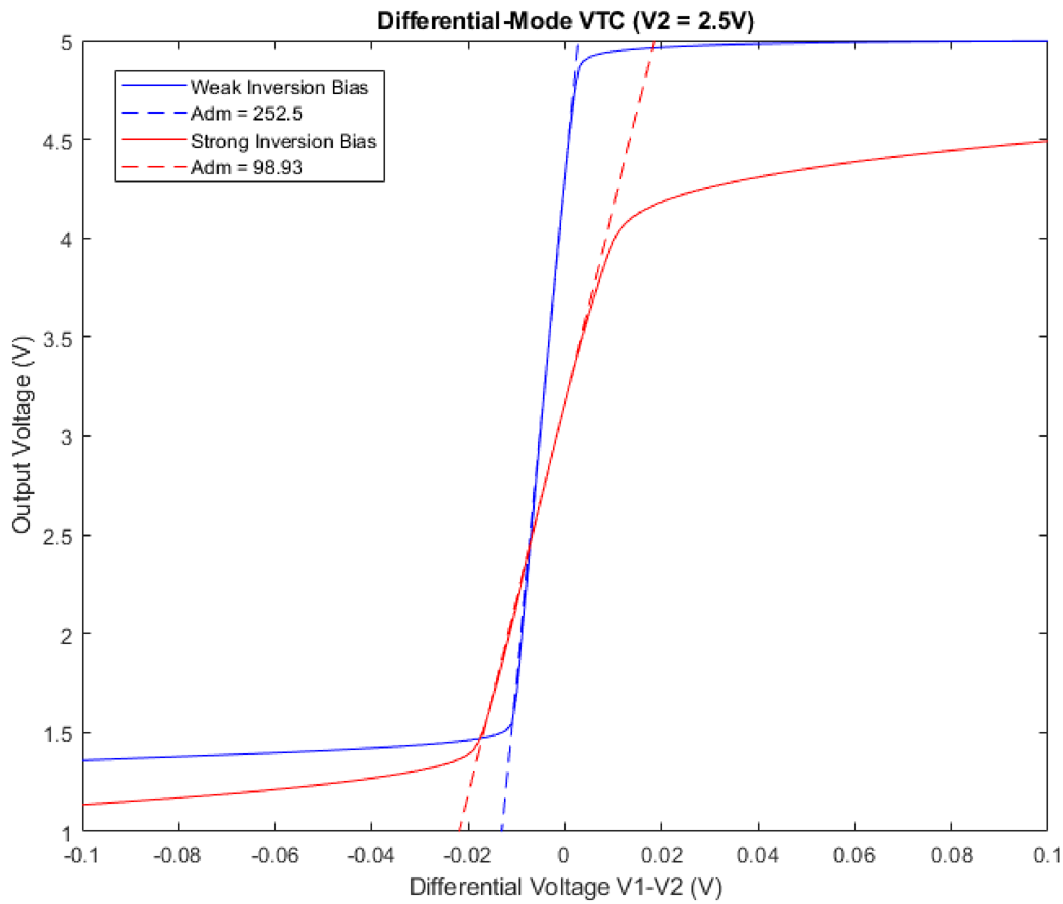

Figure 3: The output voltage as a function of the differential mode voltage.

From the line fitted to the straight regions of the graphs in figure 3, we were able to determine the differential mode voltage gain. This value is 252.5 in weak inversion and 98.93 in strong inversion.

Then, we set the Vdm to 0 and measured the current into the output of the amplifier as a function of Vout (swept from one rail to the other).

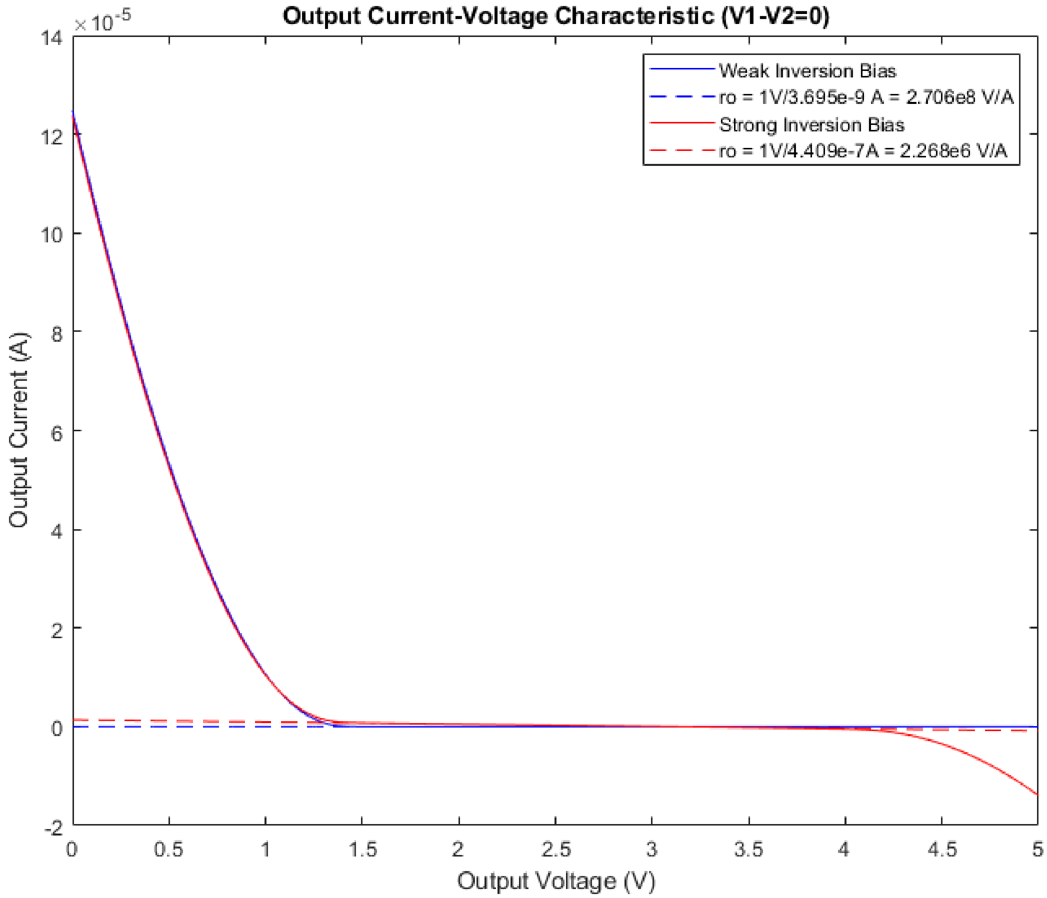

Figure 4: The current flowing into the output of the amplifier as a function of Vout.

The incremental output resistance is defined as the following equation.

$$R_{out} = \frac{\delta V_{out}}{\delta I_{out}}$$

The slope of the graph above is the inverse of this. So, by inverting the slopes found, we are able to solve for the incremental output resistance.

From figure 4, we were able to fit lines to the straight regions of the graphs. The slope in weak inversion is 3.695e-9 A. Therefore, in weak inversion, the incremental output resistance is 2.706e8 V/A The slope in strong inversion is 4.409e-7 A. Therefore, in strong inversion, the incremental output resistance is 2.268e6 V/A

Lastly, we set the output voltage to a median value where the circuit's gain is still large and measured the current flowing out of the amplifier as a function of V1 which was swept around V2 in high resolution.

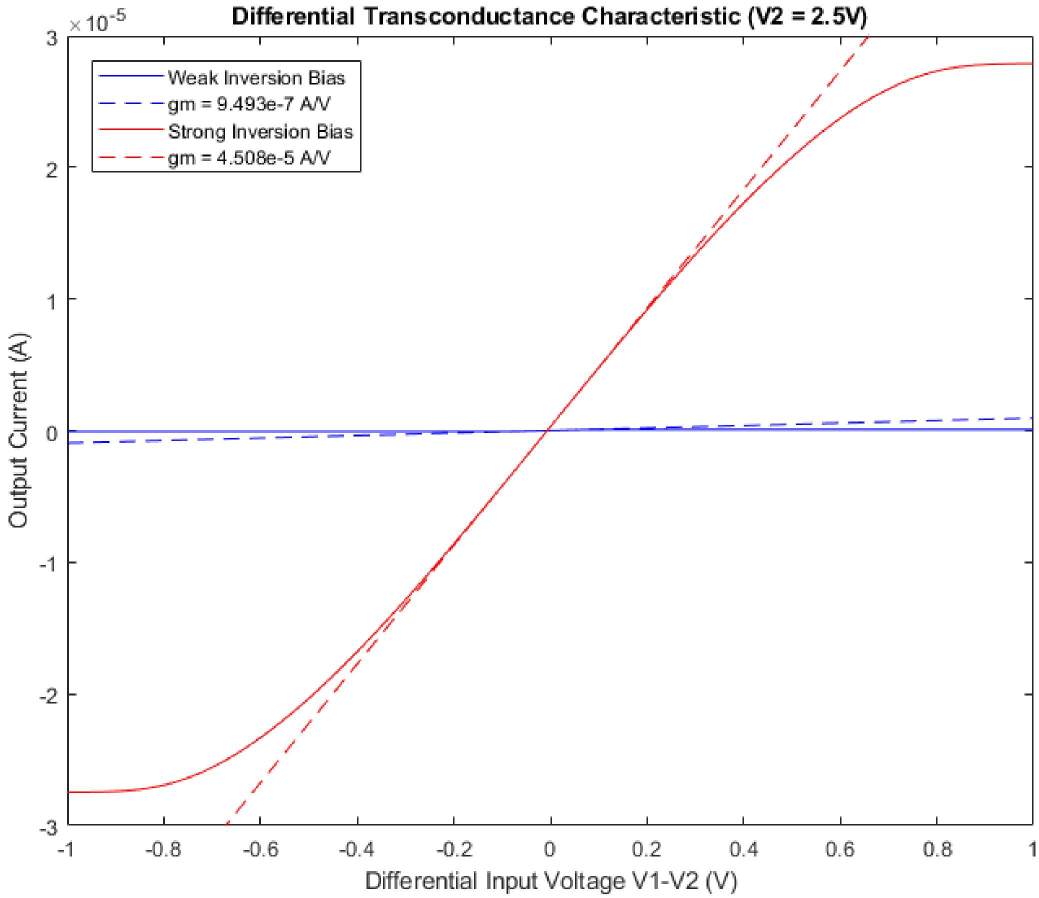

Figure 5: The current flowing out of the amplifier as function of the differential mode voltage.

We can use the slope of the lines fit to the middle linear regions of the graphs in figure 5 to determine the incremental transconductance gain from the slopes. In weak inversion, this value is 9.493e-7 Mhos. In strong inversion, this value is 4.508e-5 Mhos.

Furthermore, we can compute the incremental differential mode voltage gain of the circuit using the following equation.

$$A_{dm} = R_{out} \cdot G_m$$

Values To Calculate Incremental Differential Mode Voltage Gain

Name	Rout	Gm
Weak Inversion	2.706e8 V/A	9.493e-7 Mhos.
Strong Inversion	2.268e6 V/A	4.508e-5 Mhos

The calculated incremental differential mode gain in weak inversion is 256.88. In strong inversion, it is 102.24.

The incremental differential mode gains found from the slope of the VTC is 252.5 in weak inversion and 98.93 in strong inversion. There is a 1.71% error in the weak inversion and a 3.24% error in the strong inversion. This could have occurred due to slight linear fit differences between the three graphs as the sections to be fit to were found through qualitative graph analysis (i.e. looking at the graph).

Experiment 3: Unity-Gain Follower

In this experiment, we reconfigured the amplifier by connecting the output ot the inverting input terminal. This made the amplifier a unity-gain follower. Then, we measured Vout as a function of Vin (swept from one rail to the other).

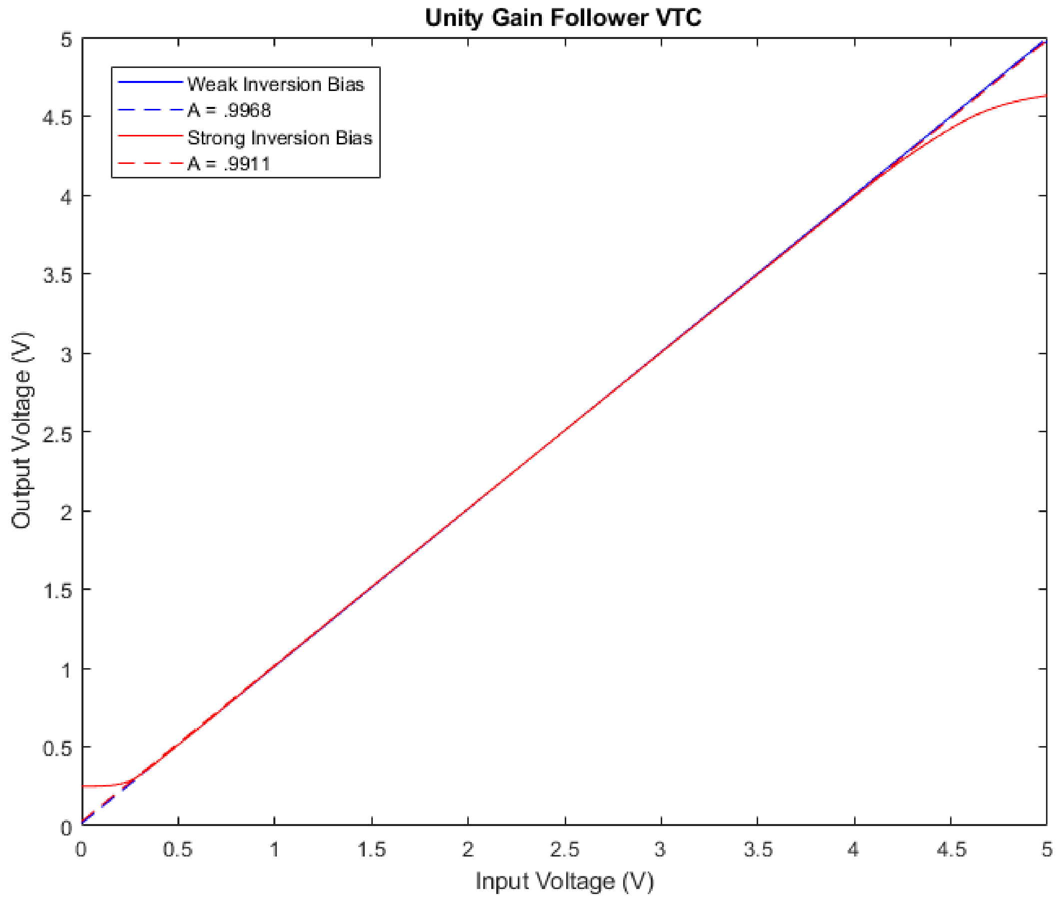

Figure 6: The voltage transfer characteristic of the unity gain follower.

The incremental voltage gain in the weak inversion is 0.9968. In strong version this value is 0.9911. These values were found through lines fit to the linear regions of the voltage transfer characteristics in strong and weak inversion. There is a percent error of .32% in the weak inversion and .89% in the strong inversion. This means that the gain values are very close to unity as they should be.

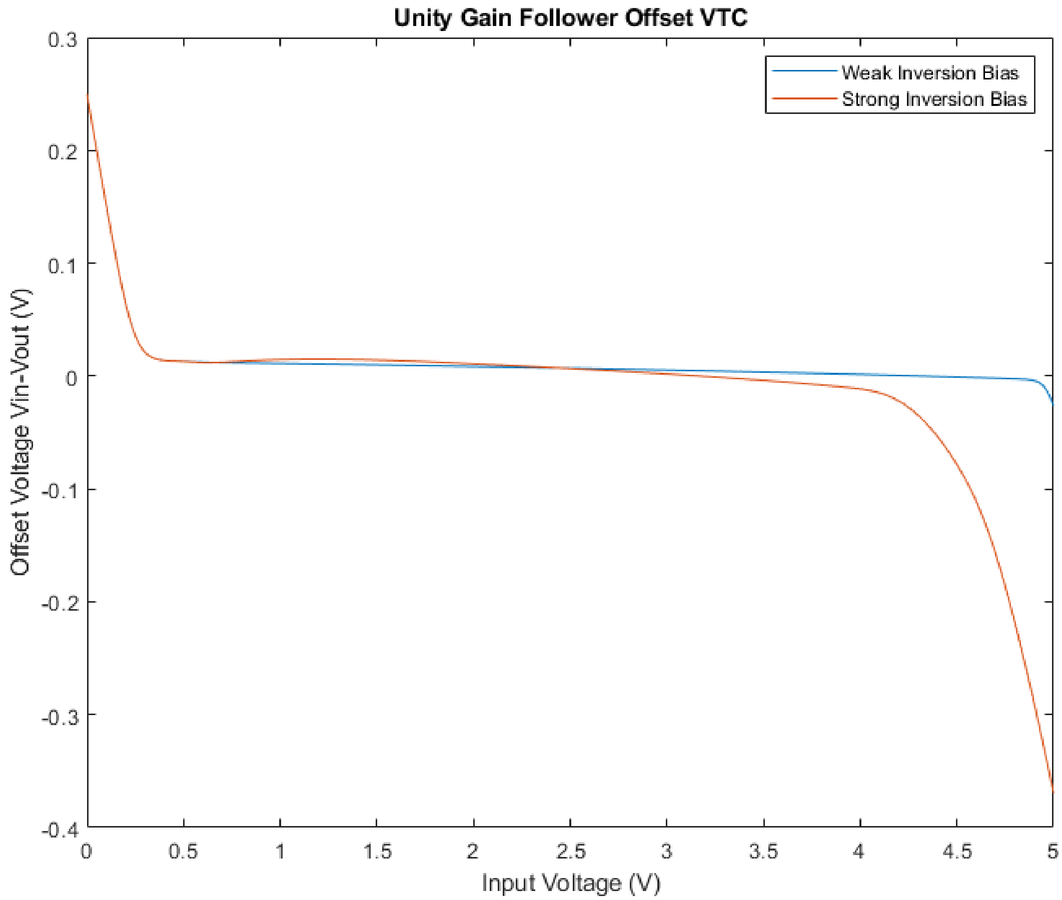

Figure 7: The voltage transfer characteristic of the unity gain follower while measuring the offset voltage.

In the weak inversion, the offset voltage stays at approximate the same value and suddenly drops off slightly once the input voltage nears the 5V mark. In the strong inversion, the offset voltage drops off from a high value to closer to zero as the input voltage increases. It then follows a similar pattern as the weak inversion offset voltage by remaining at a similar value until the input voltage nears 5V. In strong inversion, however, as voltage changes occur more gradually, the drop off is seen to occur over a longer span of voltages.