A Current-mirror Differential Amplifier

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All experiments were conducted in LTspice.

Experiment 1: Voltage Transfer Characteristicss

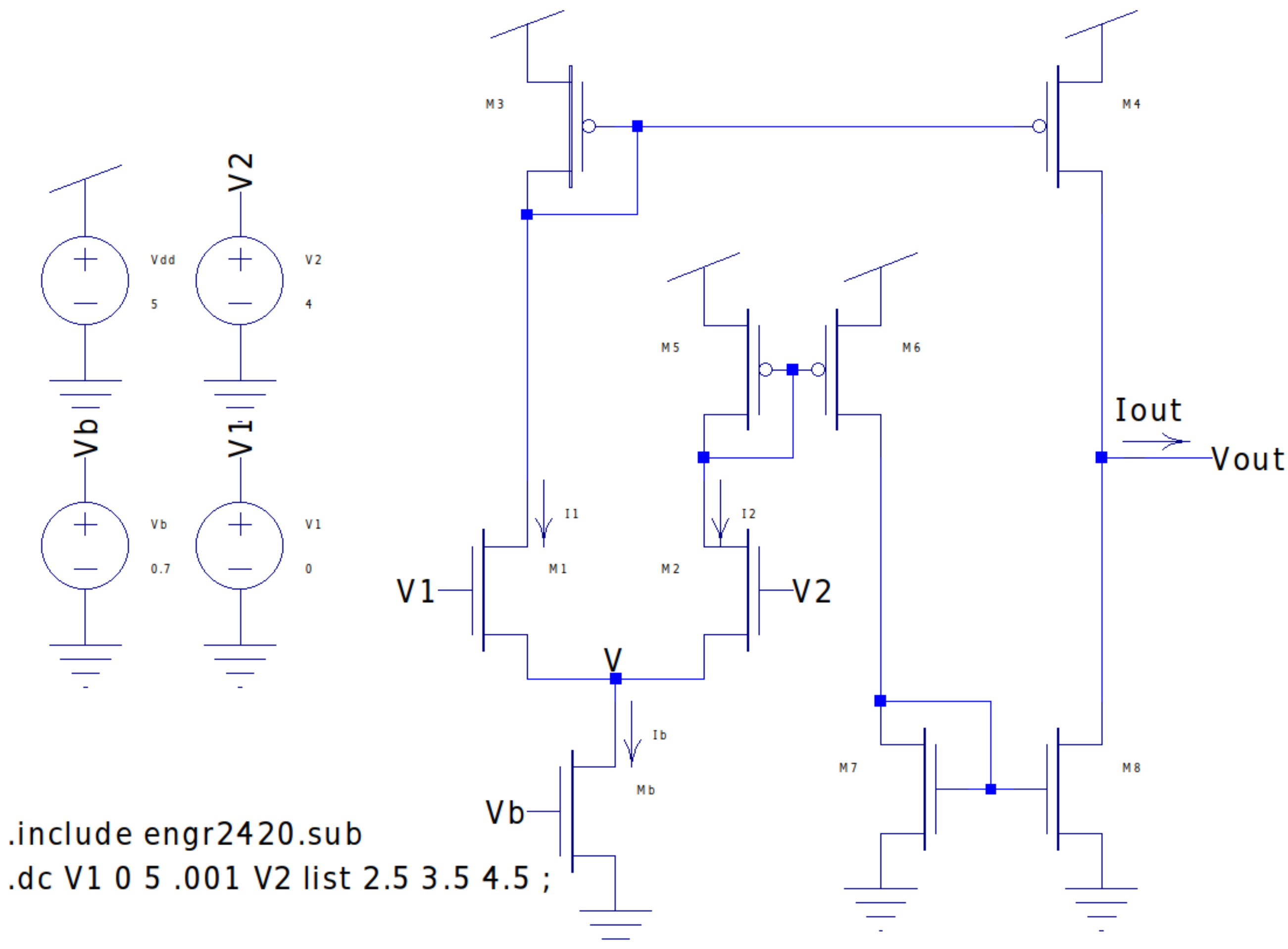

Figure 1: LTspice Schematic for Experiment 1

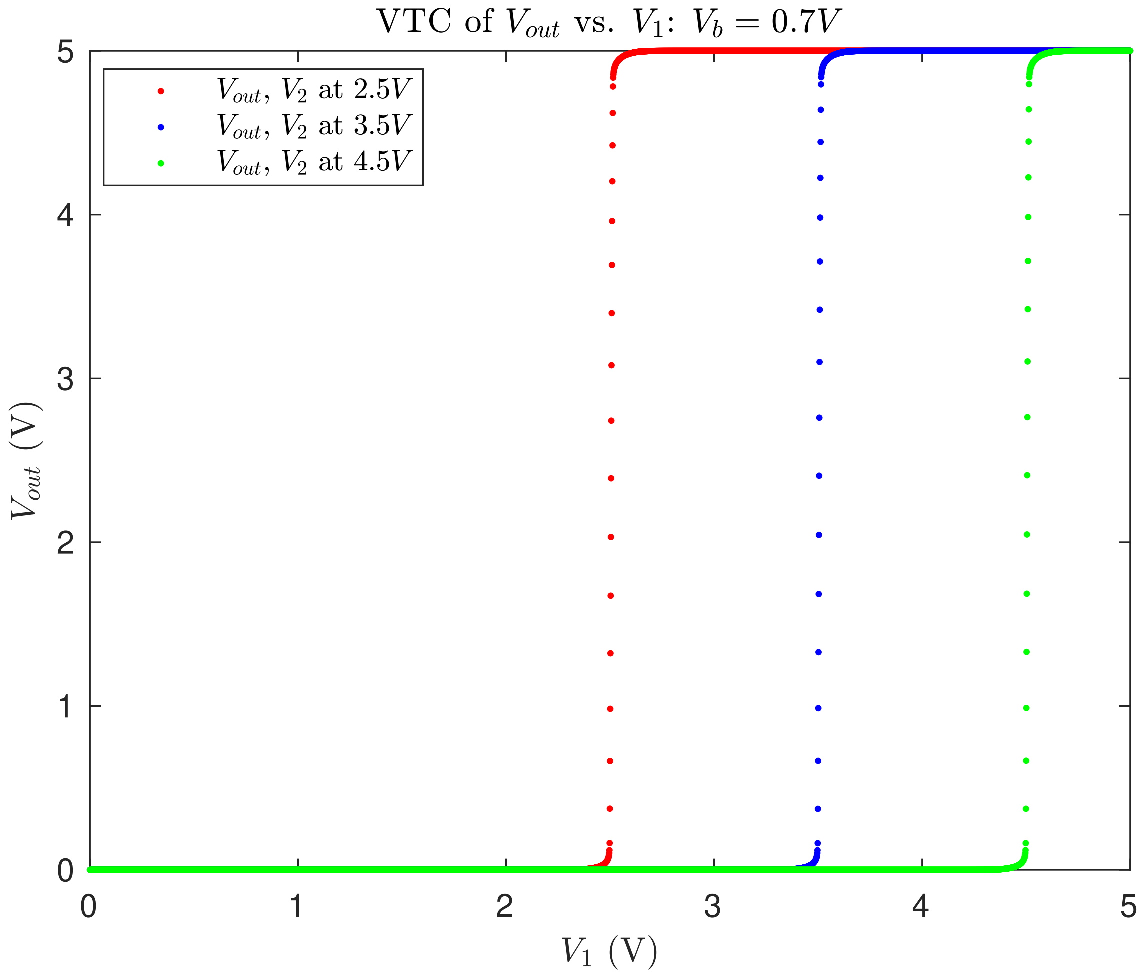

Figure 2: Voltage Transfer Characteristic at several V_{dm}

It behaves very similarly to the simple differential amplifier (lab 8) except the current mirror differential amplifier (lab 9) has a rail-to-rail output swing - the high-gain region of the VTC extends from one rail all the way to the other.

Experiment 2: Transconductance, Output Resistance, and Gain

I_{out} saturates in the positive direction at ~4.4689 $\cdot 10^{-7}$ A and saturates in the negative direction at ~-4.4612 $\cdot 10^{-7}$ A Both the extracted and the calculated value of the differential-mode gain, A_{dm} (Equation (4) and (3)), were very close to each other. These values were very close to what we derived for the simple differential amplifier differential-mode gain in Lab 8 (~308).

$$R_{out} = 79.338 \cdot 10^6 \Omega \tag{1}$$

$$G_m = 4.01 \cdot 10^{-6} \mho \tag{2}$$

$$\text{Derived } A_{dm} = R_{out} \cdot G_m = 318.14 \tag{3}$$

$$\text{Measured } A_{dm} = 322.468 \tag{4}$$

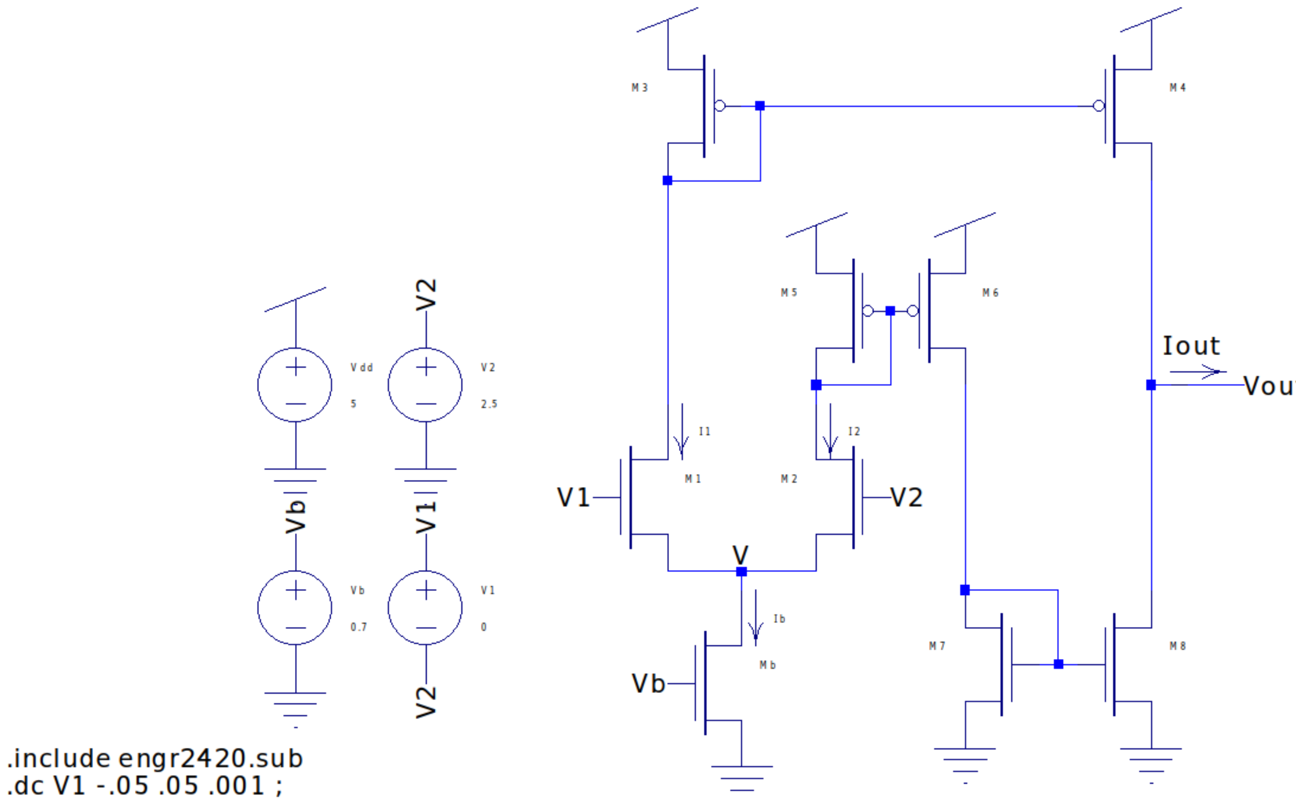

Figure 3: LTspice Schematic for Experiment 2

Experiment 3: Unity-Gain Follower Step Response

For the unity-gain follower response, we configured our circuit as seen in Figure 7. The response to a small-amplitude input change is seen in Figure 8, and the response to a large amplitude input change is seen in Figure 9. The extracted time constants and slew rates for the rising and falling behavior is shown in Table 1.

Change type	Time Constant (for small changes)	Slew Rate (for large changes)
Rising	$200.37\mu s$	$439.47V/s$
Falling	$187.94\mu s$	$-493.87V/s$

Table 1: Table of extracted fit values for both rising and falling changes to V_{in}.

For the small-amplitude input change response, the response is fairly symmetrical - there is an exponential decay characteristic in both the rising and falling cases. The extracted time constants for both cases are also on the same order of magnitude. However, the behaviour is not really linear - plotting the log of the output response still shows nontrivial curvature. The theoretical value of $\tau = \frac{C}{G_m}$ based on fits in Experiment 2 is $249.38\mu s$, which is on the same order of magnitude as the extracted fit values for τ.

For the large-amplitude input change response, the response is fairly symmetrical - the output voltage displays a linear change towards the input voltage in both cases. The extracted slew rates for both cases are also on the same order of magnitude. The theoretical value for the slew rate is found by $\frac{I_b}{C}$. If we use $I_s \approx 1\mu A$ as the limiting value for our I_b current, the maximum slew rate we get is around $1000^V/_s$. It's about twice the value that we found via the fits, and so is still within the same order of magnitude. Our reasoning for this is that our calculation is too high - in it, we don't account for the effects of the multiple current mirrors in the circuit, which could be reducing the actual slew rate.

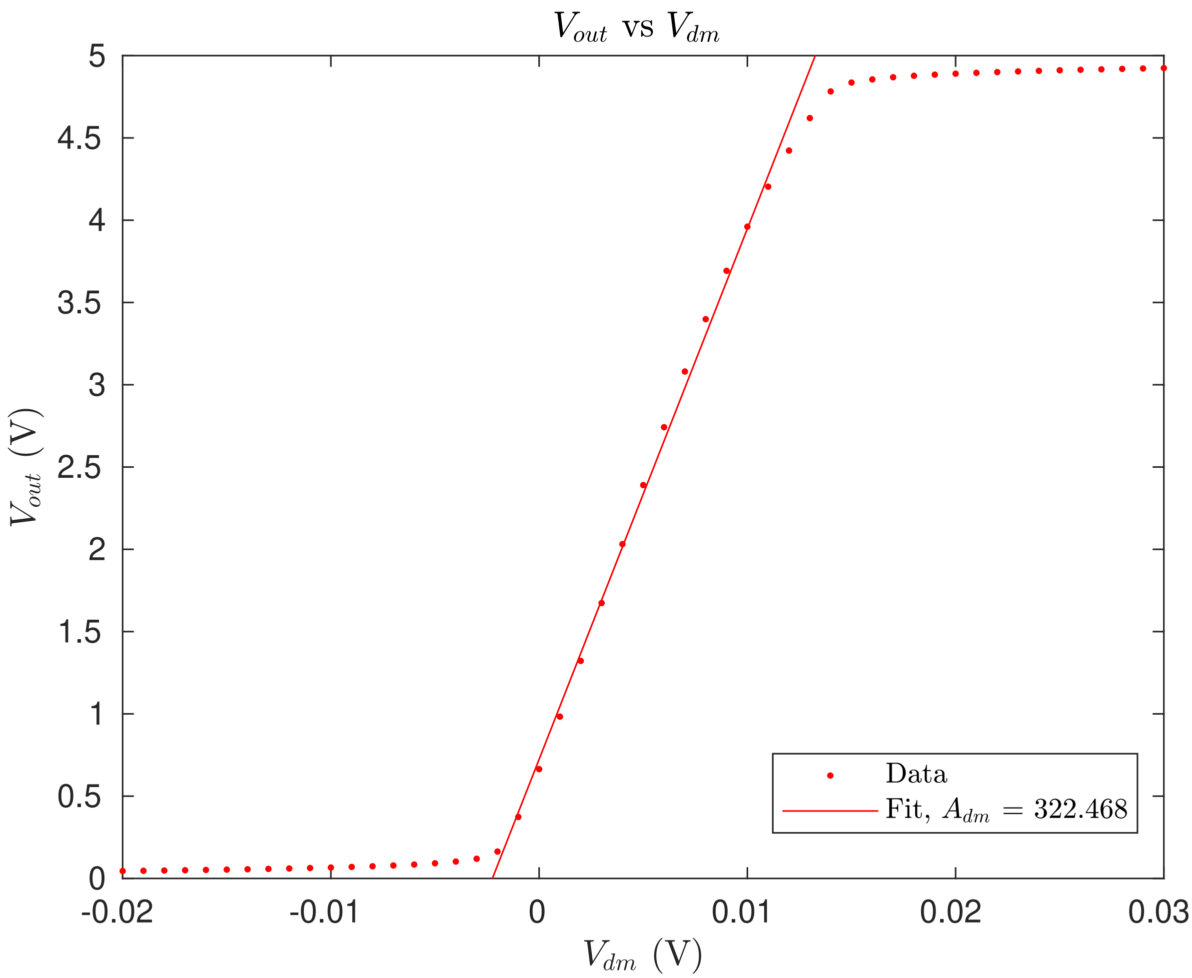

Figure 4: Voltage Transfer Characteristic for V_{out} vs V_{dm}

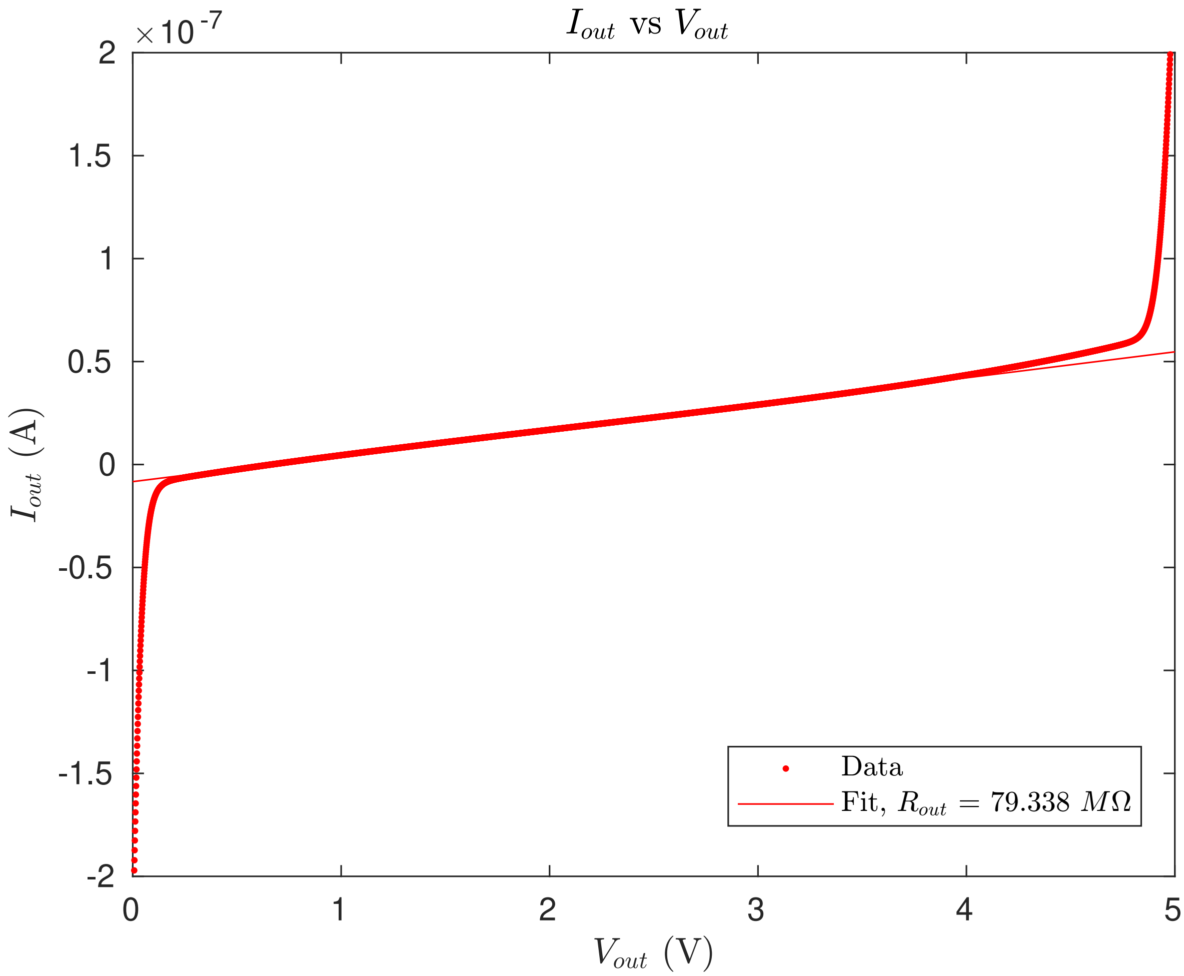

Figure 5: Incremental Output Resistance. Very dense sampled data (graph has many, many discrete points).

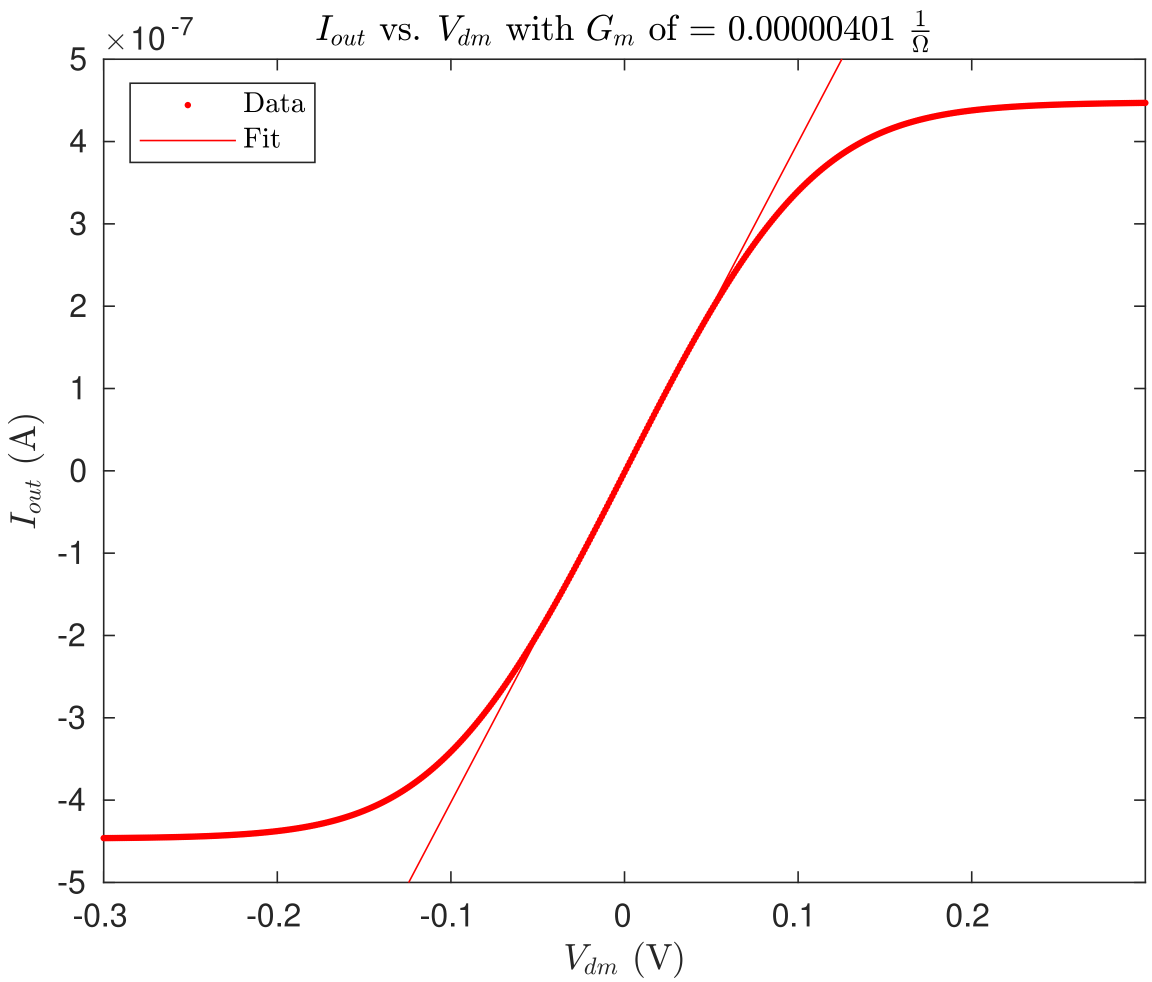

Figure 6: Incremental Transconductance Gain. Very dense sampled data (graph has many, many discrete points).

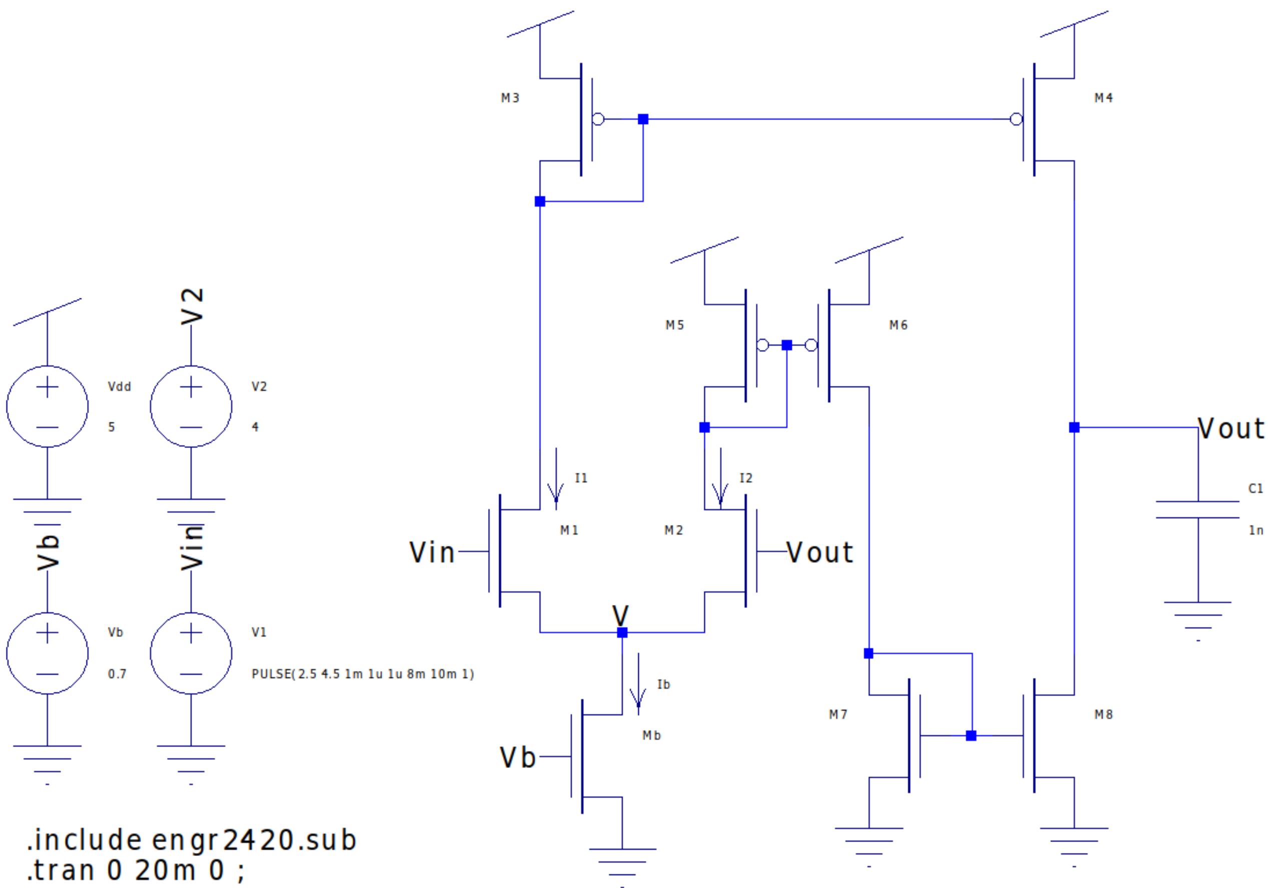

Figure 7: LTspice Schematic for Experiment 3

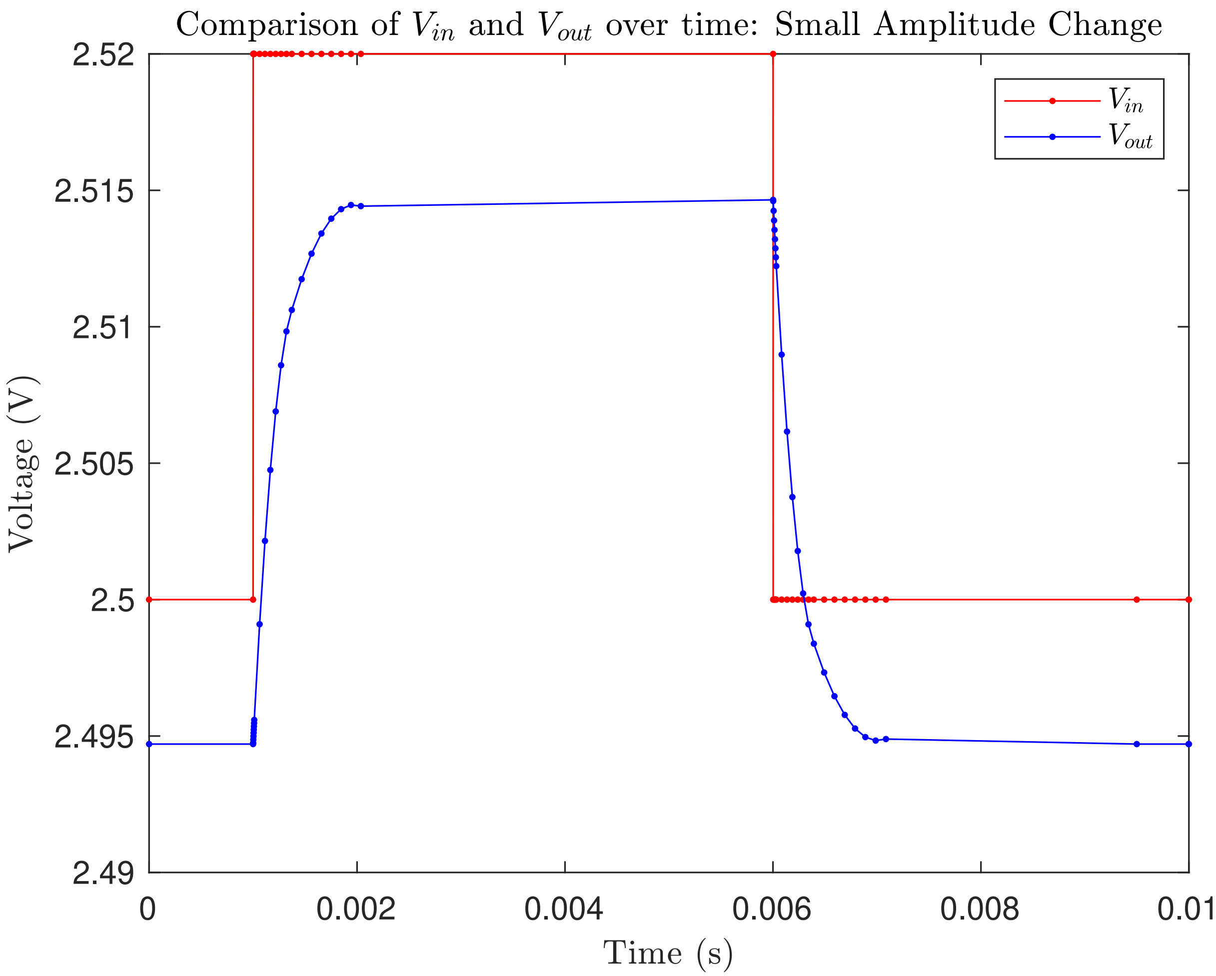

Figure 8: V_{in} and V_{out} response for a small-amplitude input change

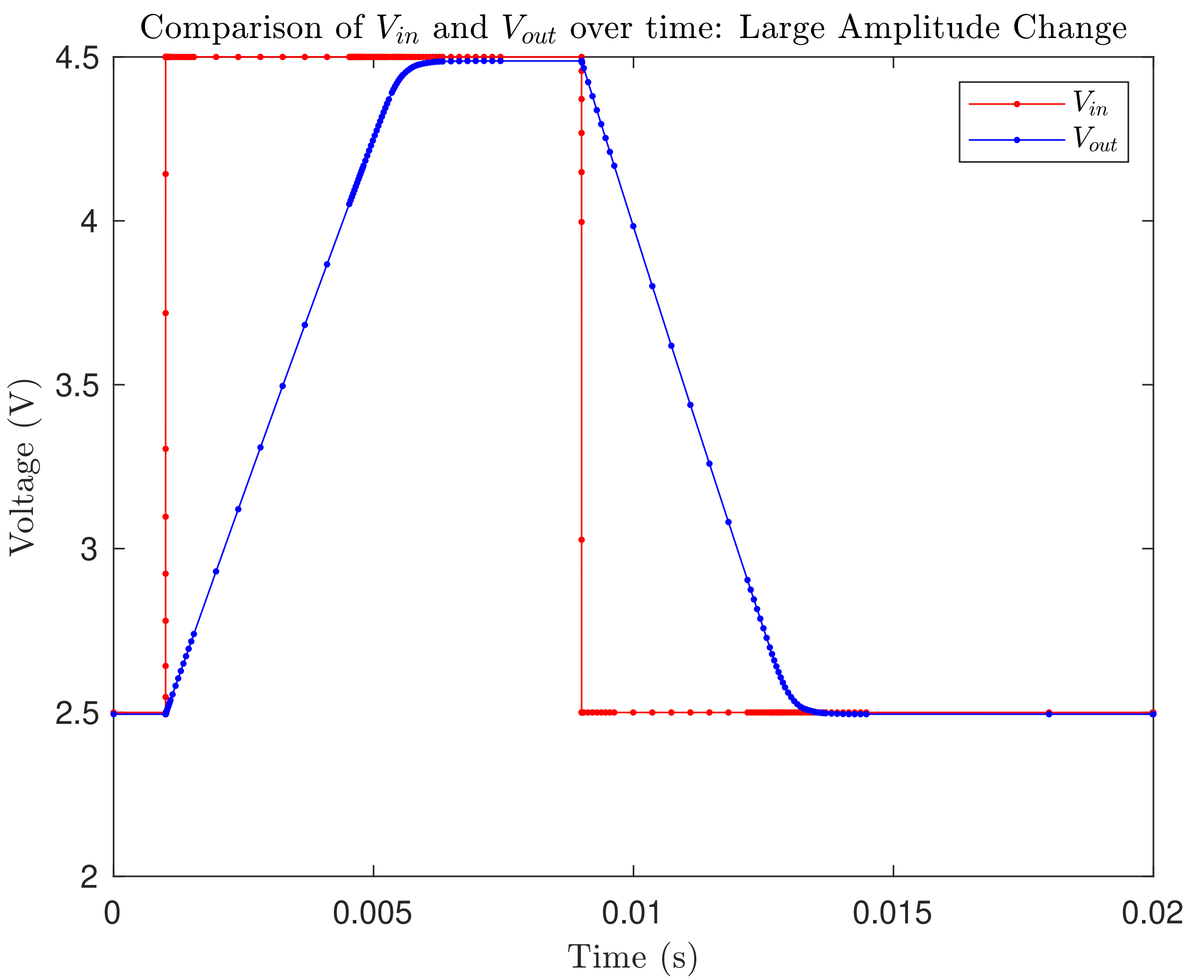

Figure 9: V_{in} and V_{out} response for a large-amplitude input change