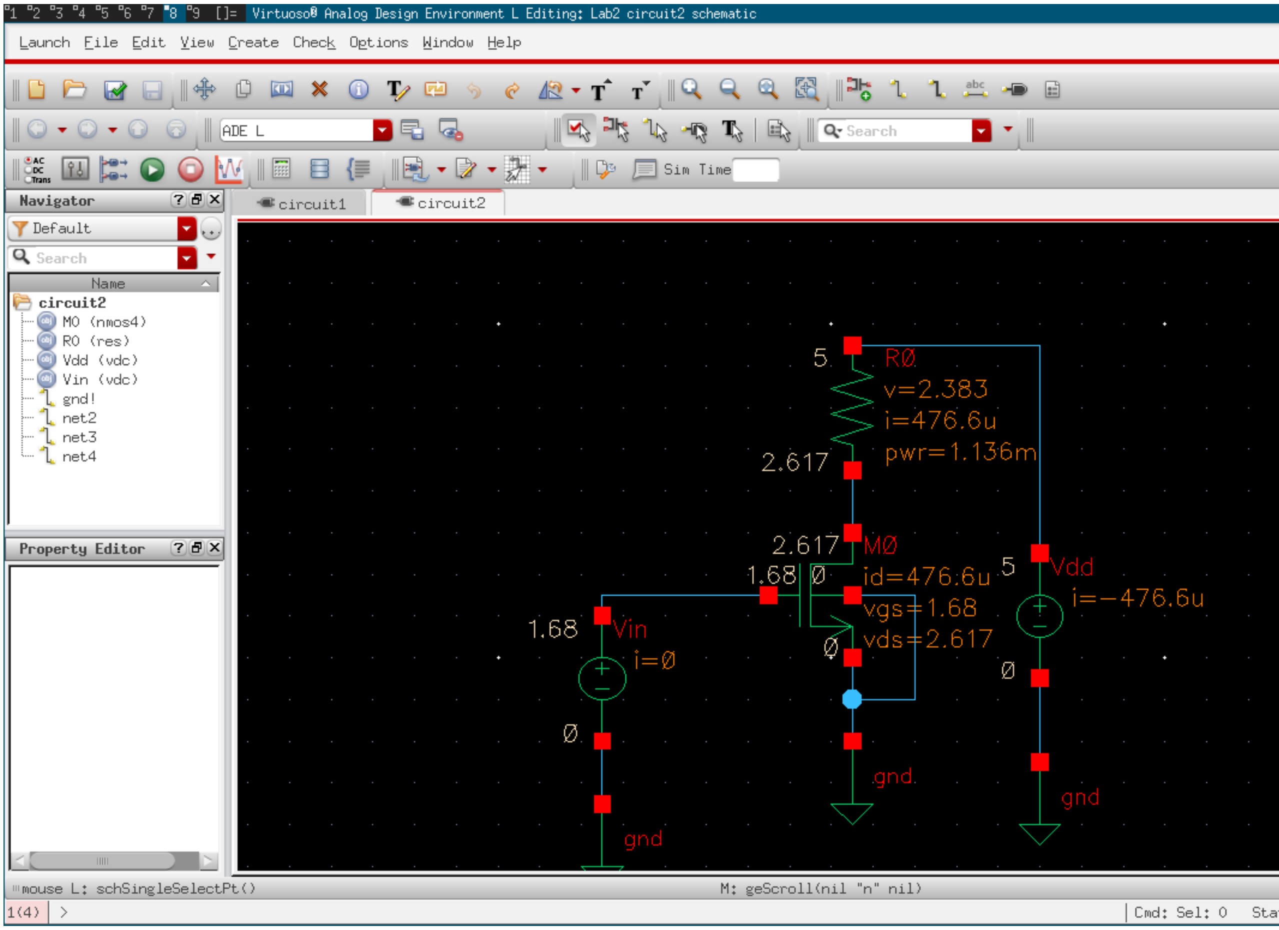

Figure 1: Common-Source Amplifier

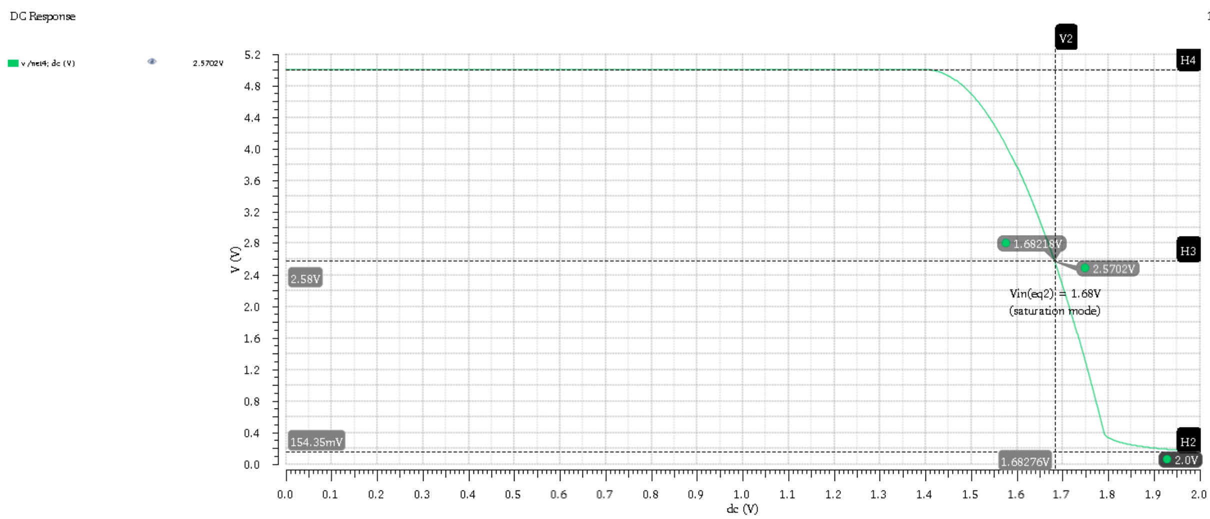

Figure 2: Voltage Transfer Characteristic for Common-Source Amplifier

$V_{in(eq2)} = 1.68$V for this particular amplifier. The transistor operates in the saturation region at this point. Common-source amplifiers start in cutoff mode for V_{in} below the threshold voltage V_{tn}. When V_{in} is too large, they typically enter the triode mode. For the region in between these two modes, the amplifier operates in saturation. Figure (1) shows the results of a DC operating point simulation. These results can be used to calculate g_m and r_o.

Table 1: g_m for Common-Source Amplifier

gm from Op Point Listing [mA / V]	Calculated gm [mA / V]	Error from Listing
3.41	3.40	0.02%

Table 2: r_o for Common-Source Amplifier

ro from Op Point Listing [kiloohms]	Calculated ro [kiloohms]	Error from Listing
600.24	610.31	1.68%

The simulation tool's result for r_o likely accounts for higher-order effects. As a result, the calculation used herein is naive, and Virtuoso's result for r_o is to be used instead in subsequent calculations.

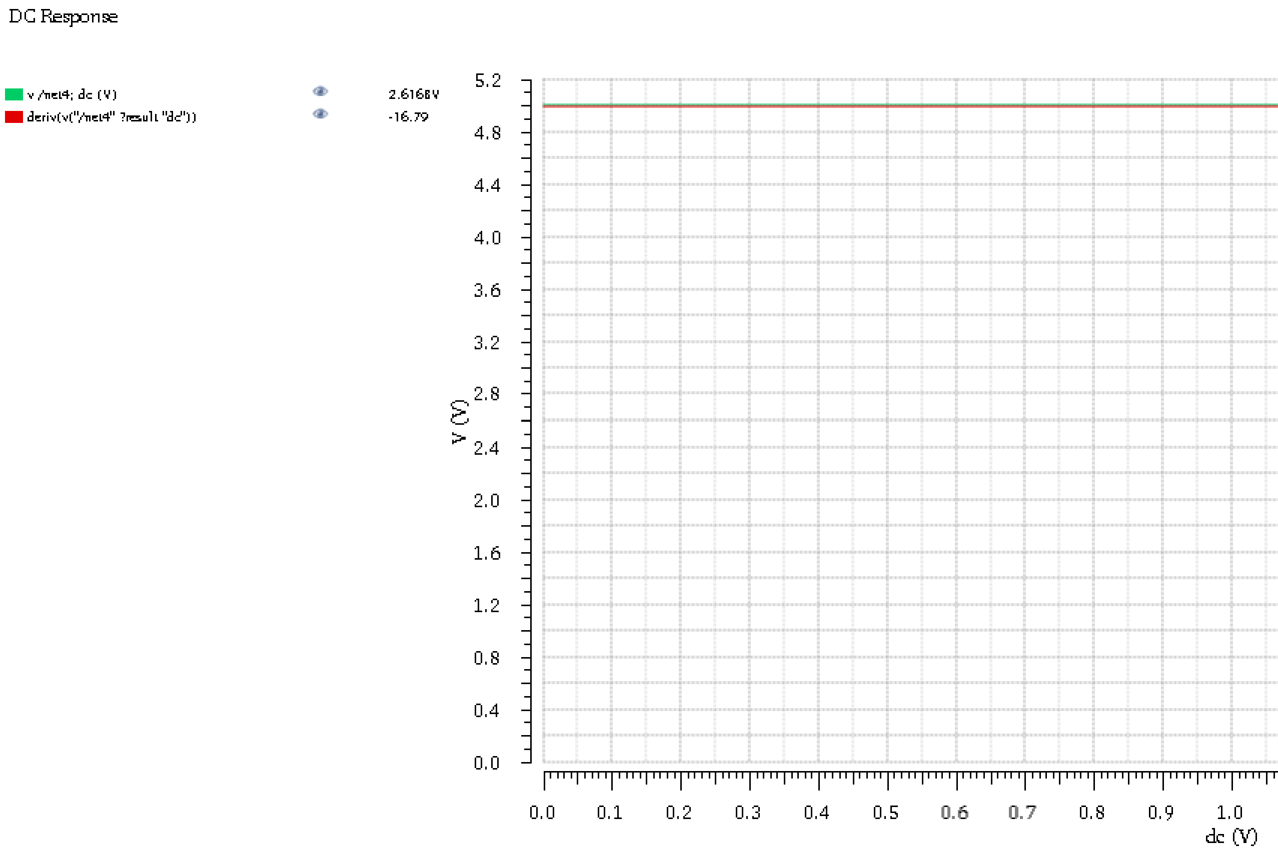

Figure 3: Common-Source Amplifier Voltage Transfer Characteristic with $\frac{dV_{out}}{dV_{in}}$ in Red

At $V_{in(eq2)}$, the gain $\frac{dV_{out}}{dV_{in}}$ turns out to be about -16.79. The gain can be calculated using the expression $A_v = -g_m(R_D||r_o)$.

Table 3: Common-Source Amplifier Gain

Gain from Graph [V/V]	Gain from Theory [V/V]	Error from Theory
-16.79	-16.82	0.00%

The small-signal behavior of the common-source amplifier is then analyzed. A 1mV amplitude, 1MHz sine wave is applied at the gate when the transistor is biased at $V_{in(eq2)}$.

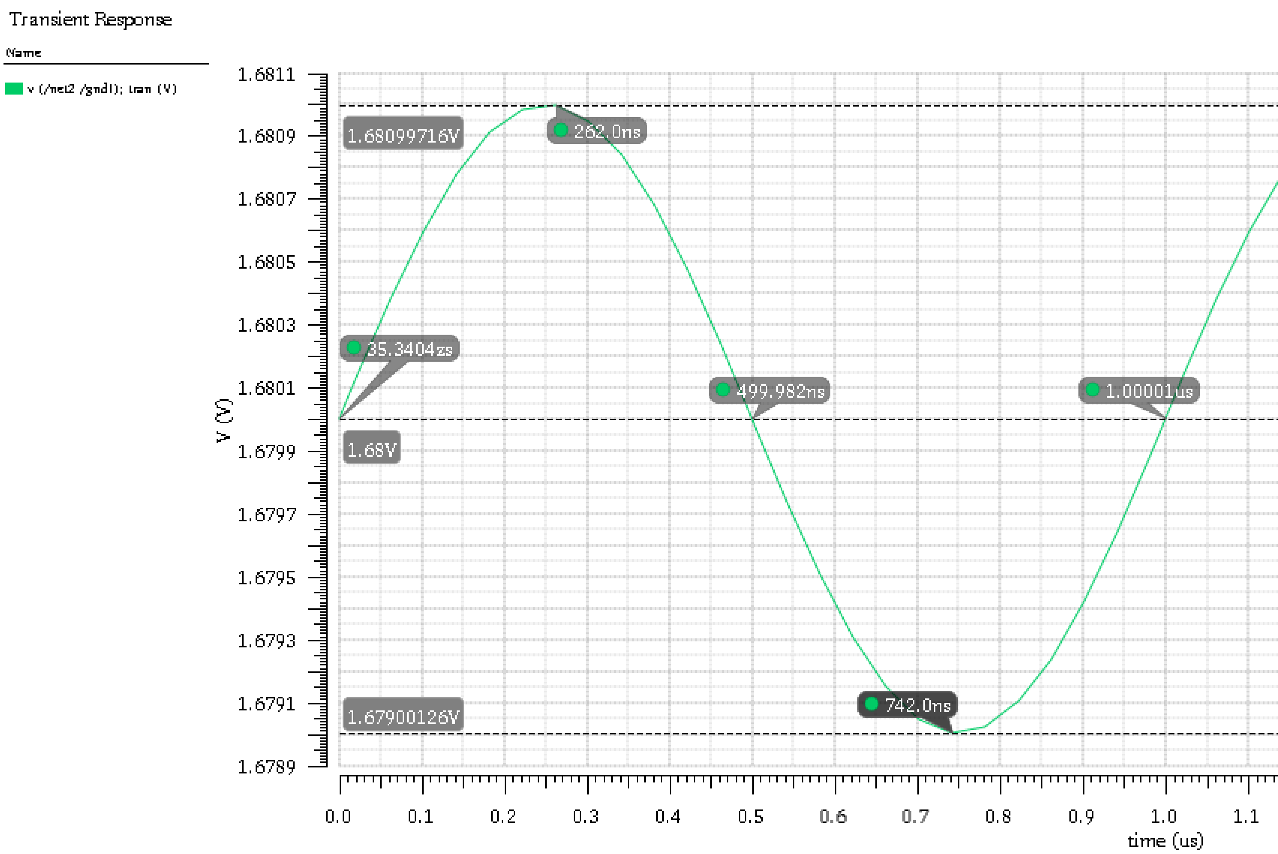

Figure 4: V_{in} Small-Signal Test of Common-Source Amplifier

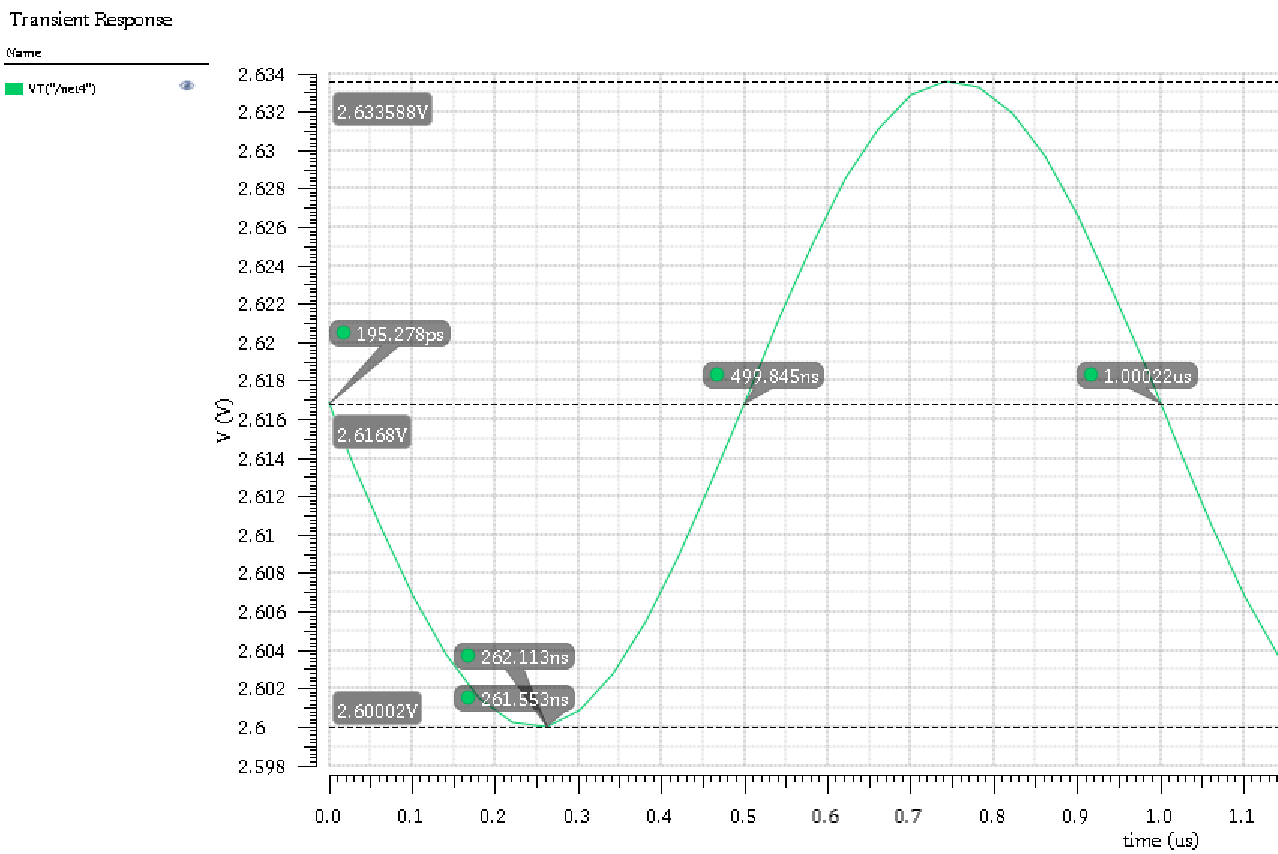

Figure 5: V_{out} Small-Signal Test of Common-Source Amplifier

The output signal is biased at the output voltage when $V_{in(eq2)}$ is applied at the gate of the transistor, whereas the input signal is biased at $V_{in(eq2)}$. The ratio of the output signal's amplitude to the input signal's amplitude is about 16.8, in line with the theoretical gain prediction and gain acquired from simulation plots. The output signal is also out of phase by 180^o, which is consistent with the fact that the gain is negative.

The input bias is then increased by 10mV.

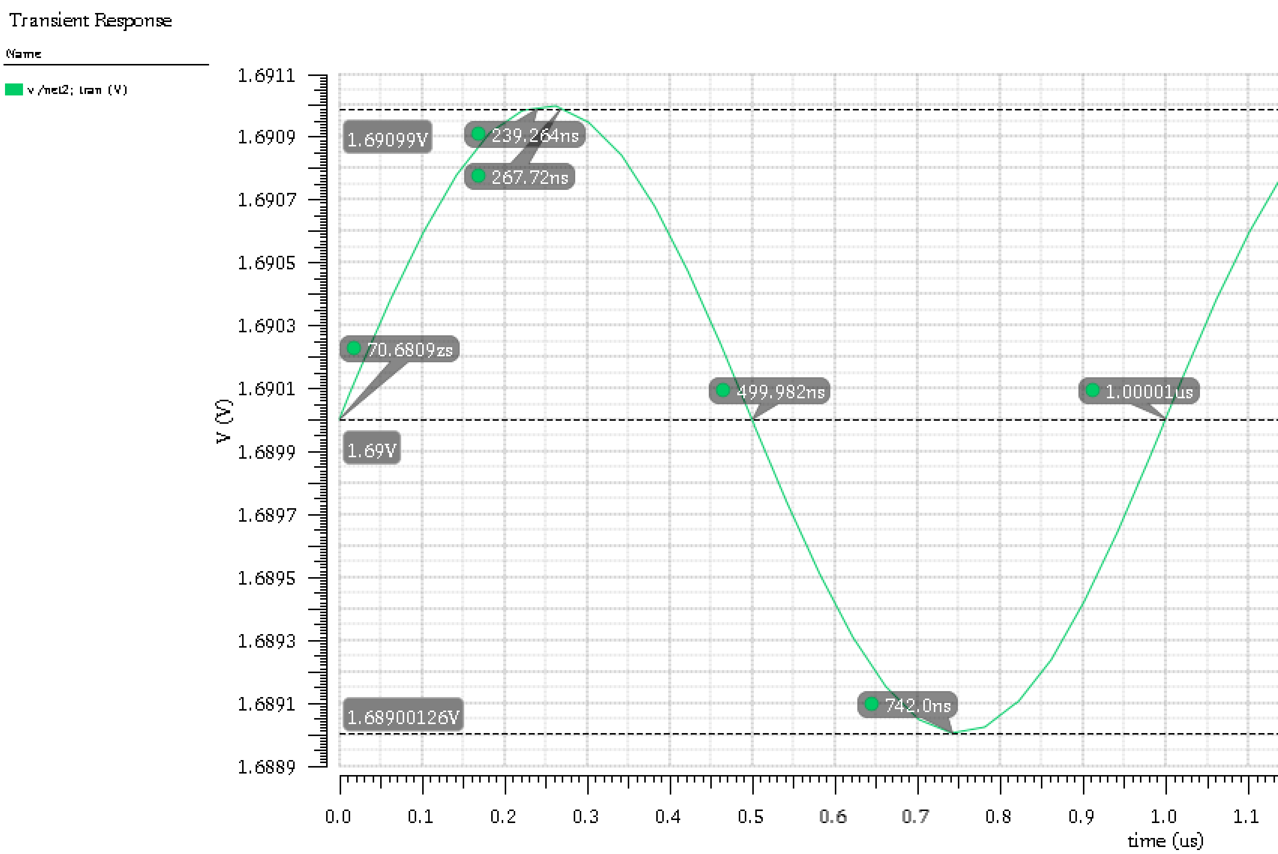

Figure 6: V_{in} for Small-Signal Test of Common-Source Amplifier after Increasing Input Bias by 10mV

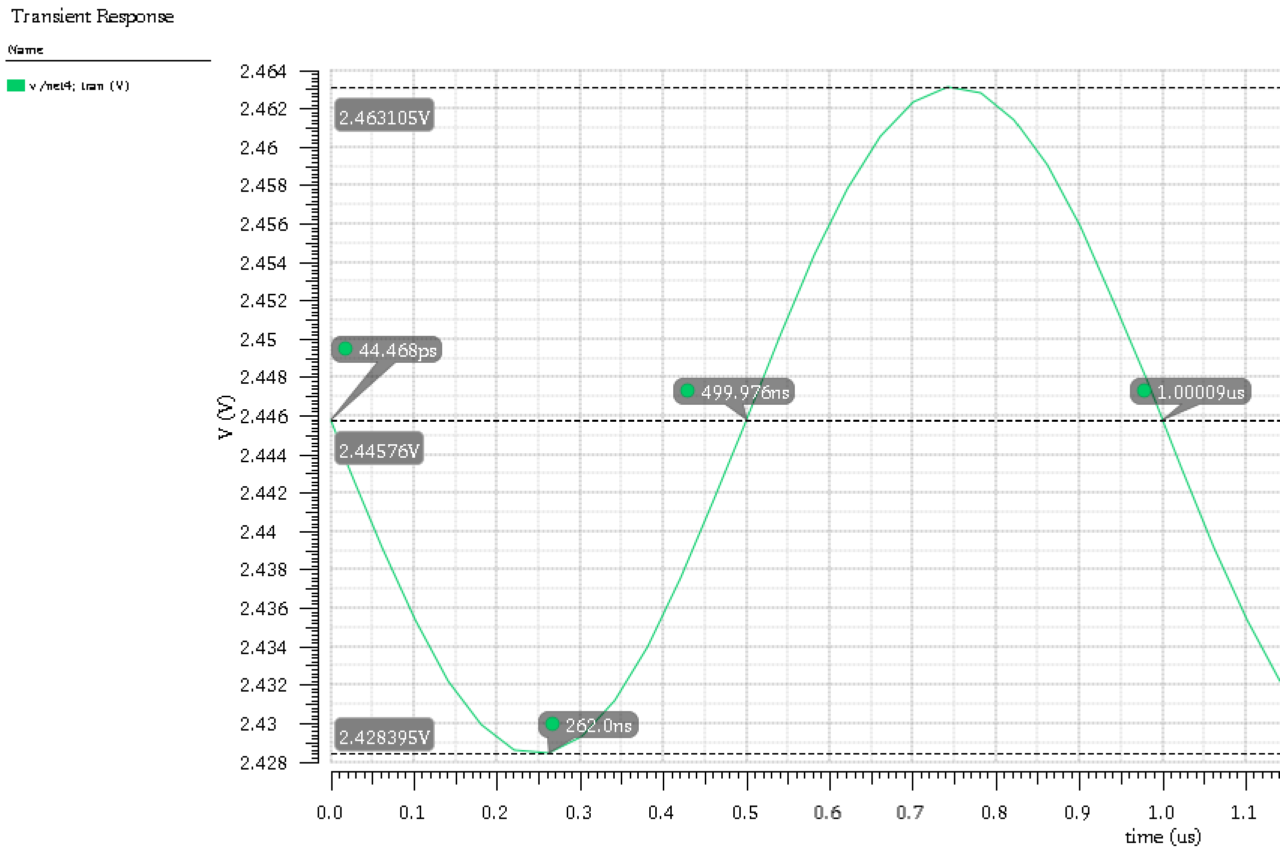

Figure 7: V_{out} for Small-Signal Test of Common-Source Amplifier after Increasing Input Bias by 10mV

The output bias drops by roughly the gain of the amplifier times the change in the input bias 10mV, precisely the behavior that is expected since the gain is directly related to the slope of the voltage transfer characteristic. However, the gain appears to have increased in magnitude to about -17.4V. Thus, the gain of a common-source amplifier increases as the bias voltage is increased past the midpoint. It should be noted that this is at the expense of output voltage swing.