EEEE 380 Exercise 2

Design and Simulation of NMOS Inverters

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By submitting this report, you attest that you neither have given nor have received any assistance (including writing, collecting data, plotting figures, tables or graphs, or using previous student reports as a reference), and you further acknowledge that giving or receiving such assistance will result in a failing grade for this course.

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Abstract

In this exercise, the behaviour of RTL and SEL inverters was investigated by simulating the circuits in SPICE. The effects of varying different parameters inside the load device (resistance and load transistor strength) was investigated. VTC curves were shown for both of the inverter types as well as plots for inverter response due to varying parameters.

RTL Inverter

The resistor-transistor inverter is an inverter with a resistor load and transistor driver. A VTC curve was simulated in LT-SPICE.

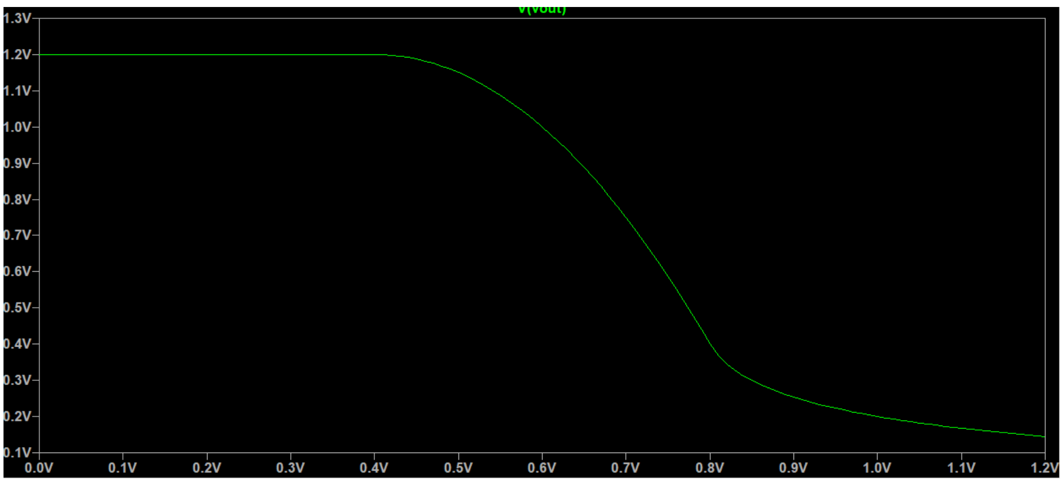

Figure 1: Base RTL VTC curve

Figure 1 shows that V_{OH} will reach the V_{DD} which is expected with the RTL inverter. V_{OL} will not drop below $0.15V$ due to the driver strength not being strong enough to overcome the resistor load.
To show the relationship between the V_{OL} and the resistance of the load, three simulations were performed with varying resistances.

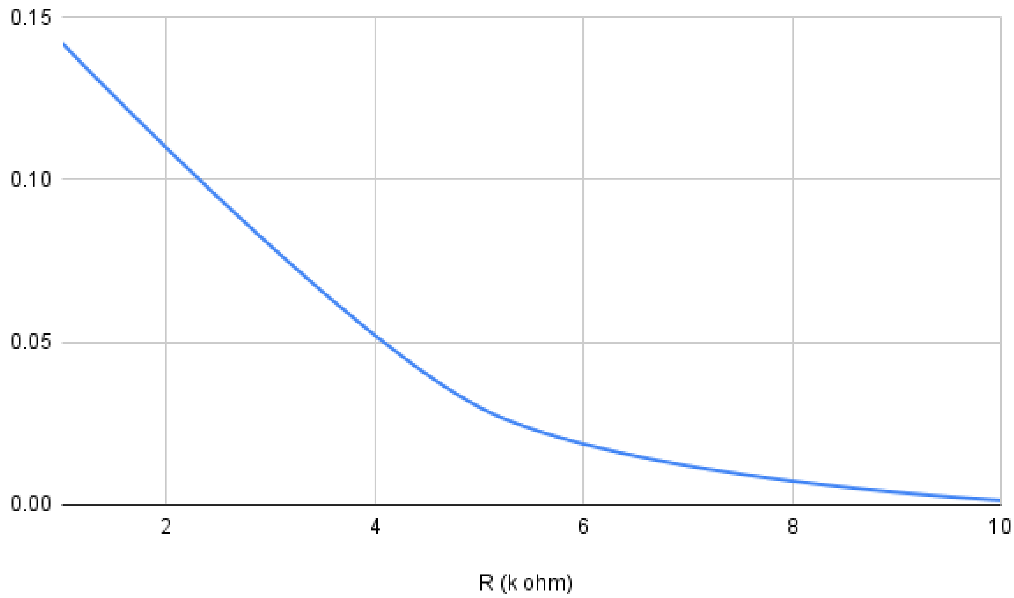

Figure 2: V_{OL} vs R

Figure 2 shows that as the resistance increases, V_{OL} drops to near $0V$. Figure 2 shows the behaviour of the VTC curve in response to a change in the characteristics of the load. This exercise also looked at the behaviour in response to a change in the strength of the driver. To do this, the driver transistor's width was varied there-by changing its strength relative to the load.

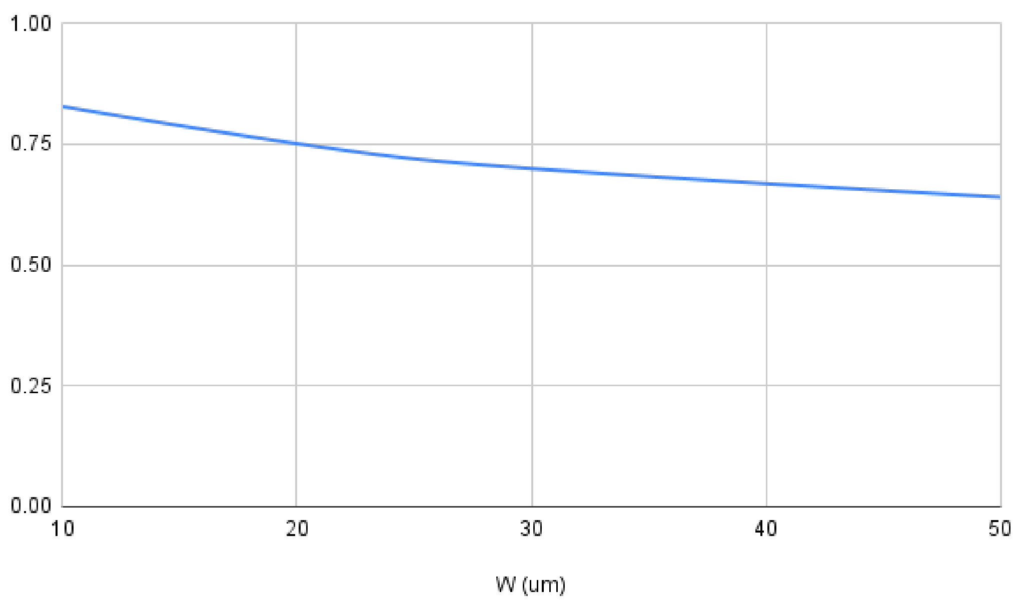

Figure 3: V_{th} vs W

Saturated enhancement-load inverter

The saturated enhancement-load inverter works by wiring two enhancement NMOS devices in series. The drain of the load is connected to V_{DD} while the drain of the driver is connected to the output. The driver's gate is the input and the load's gate is V_{DD}. Due to the threshold voltage of the load and its body effect, V_{OH} will not reach V_{DD} as there will always be a voltage drop across the load device.

To show the characteristic response of the SEL inverter to the presence of body effect, two VTC curves were generated with $\gamma = 0V^{1/2}$ and $\gamma = 0.2V^{1/2}$.

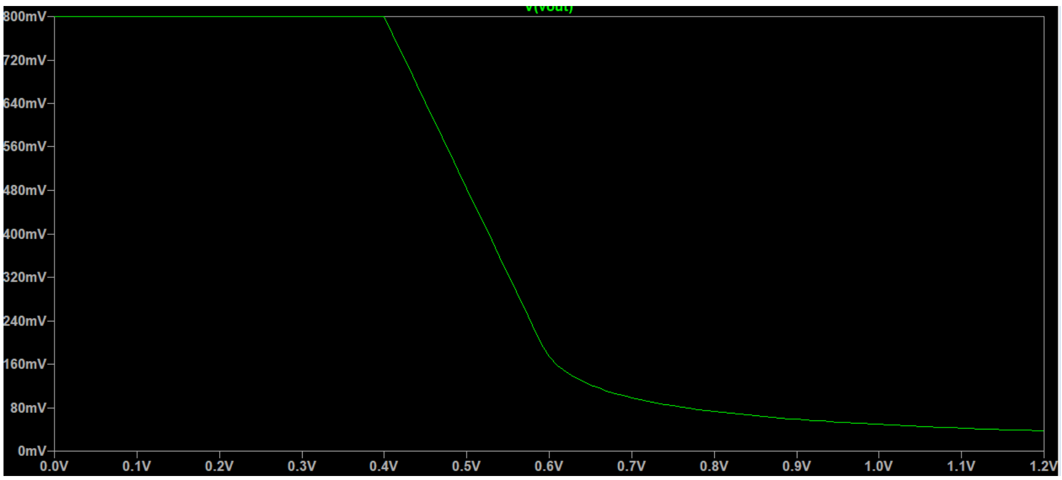

Figure 4: SEL VTC without body effect on load NMOS

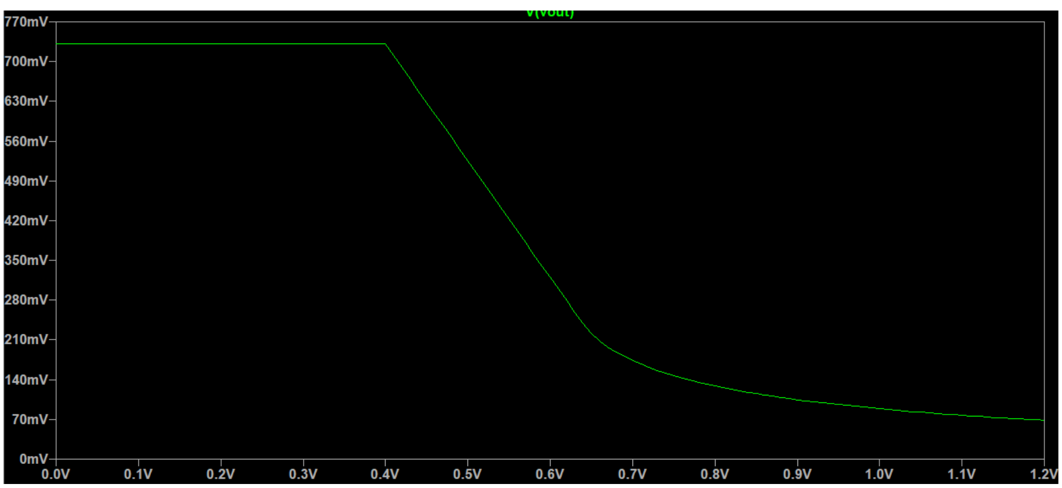

Figure 5: SEL VTC with body effect $\gamma = 0.2V^{1/2}$ on load NMOS

The SEL inverter will not reach a V_{OH} equal to its high supply V_{DD}. Without body effect, this voltage reach $0.8V$ with a V_{DD} of $1.2V$. With body effect, the voltage only reaches $0.731V$. This is expected as the response due to body effect should decrease V_{OH} according to the prelab calculations. Due to V_{OH} dropping in response to body effect, V_{OL} is expected to rise as the input voltage for a low output will not be lower. As expected, V_{OL} rises from $0.073V$ to $0.091V$ when $\gamma = 0.2V^{1/2}$.

In addition to body effect, the SEL inverter's VTC curve will respond to changes in the relative strength between the driver and load. This relationship is denoted as K_r and is equivalent to k_{driver}/k_{load}. This ratio may be changed by fixing $(\frac{W}{L})_1$ and varying $(\frac{W}{L})_2$. A plot showing the effect of K_r on V_{OL} and V_{th} was generated.

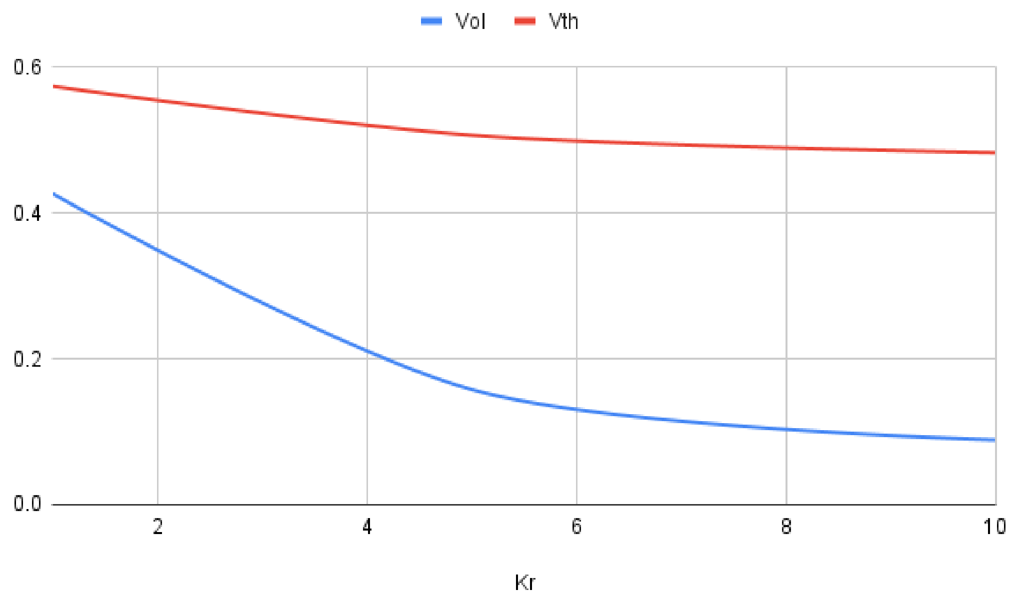

Figure 6: Effect of K_r on V_{OL} and V_{th} of SEL inverter

Figure 6 shows expected results. As the strength of the driver increases relative to the load ($k_{driver} \propto K_r$), the output low decreases. This is because the driver is able to pull the output lower.

Conclusion

This exercise investigated the RTL and SEL inverters by comparing their operations while varying characterics of each device. The behaviour of the RTL inverter was shown while varying the resistance of the load as well as the width of the driver NMOS device. The behaviour of SEL inverter was shown while by showing the VTC curve due to body effect on the load device as well as varying the relative strength of the driver to load K_r. Both the RTL and SEL inverters showed expected behavioural response in the simulations when comparing to the prelab calculations. The goals of the this exercise were reached as the circuits were successfully simulated and the prelab calculations were supported by the simulation results.