Inverter Switching Transient Analysis

The generic inverter stage (a) with the non-linear charge store shown explicitly. The charging cycle (b), and the discharging cycle (c).

The charge store will in general be a non-linear function of the output voltage; so too are the currents. Thus the differential equations we must solve are

Charging: \[ \frac{dq_N(v_{OUT})}{dt} = i_{CH}(v_{OUT}), \]

and

Discharging: \[ \frac{dq_N(v_{OUT})}{dt} = i_{DCH}(v_{OUT}). \]
These are in general very complicated and difficult to solve by any means. If, however, the charge store can be modeled as a linear capacitor, $C_L$ (i.e., $q_N \approx C_L v_{OUT}$), as illustrated below, then we can write,

Charging: $\frac{dv_{OUT}}{dt} = i_{CH}(v_{OUT})/C_L$

and

Discharging: $\frac{dv_{OUT}}{dt} = i_{DCH}(v_{OUT})/C_L$

These are now differential equations for $v_{OUT}(t)$ that we should at least be able to solve numerically, if we cannot do so analytically. They also show us the value of knowing the size and shape of $i_{CH}$ and $i_{DCH}$. (See Figure 6.14 in the course text, and the discussion accompanying it, for more on this topic).

![Diagram of charging and discharging cycles](image)

Charging (a) and discharging (b) cycles with a linear load capacitor and zero static load current. Note that for MOS inverters the static current into the stage load, $i_{SL}(v_{OUT})$, is zero.

Finally, if the charge store can be modeled as a linear capacitor and the charging and discharging currents can also be approximated as being constant, then

$\tau_{LO\rightarrow HI} \approx \frac{C_L(V_{HI} - V_{LO})}{I_{CH}}$

and

$\tau_{HI\rightarrow LO} \approx \frac{C_L(V_{HI} - V_{LO})}{I_{DCH}}$

We will find that we can use such an approximation to advantage when we are analyzing CMOS inverters.