6.012 - Microelectronic Devices and Circuits – Fall 2009

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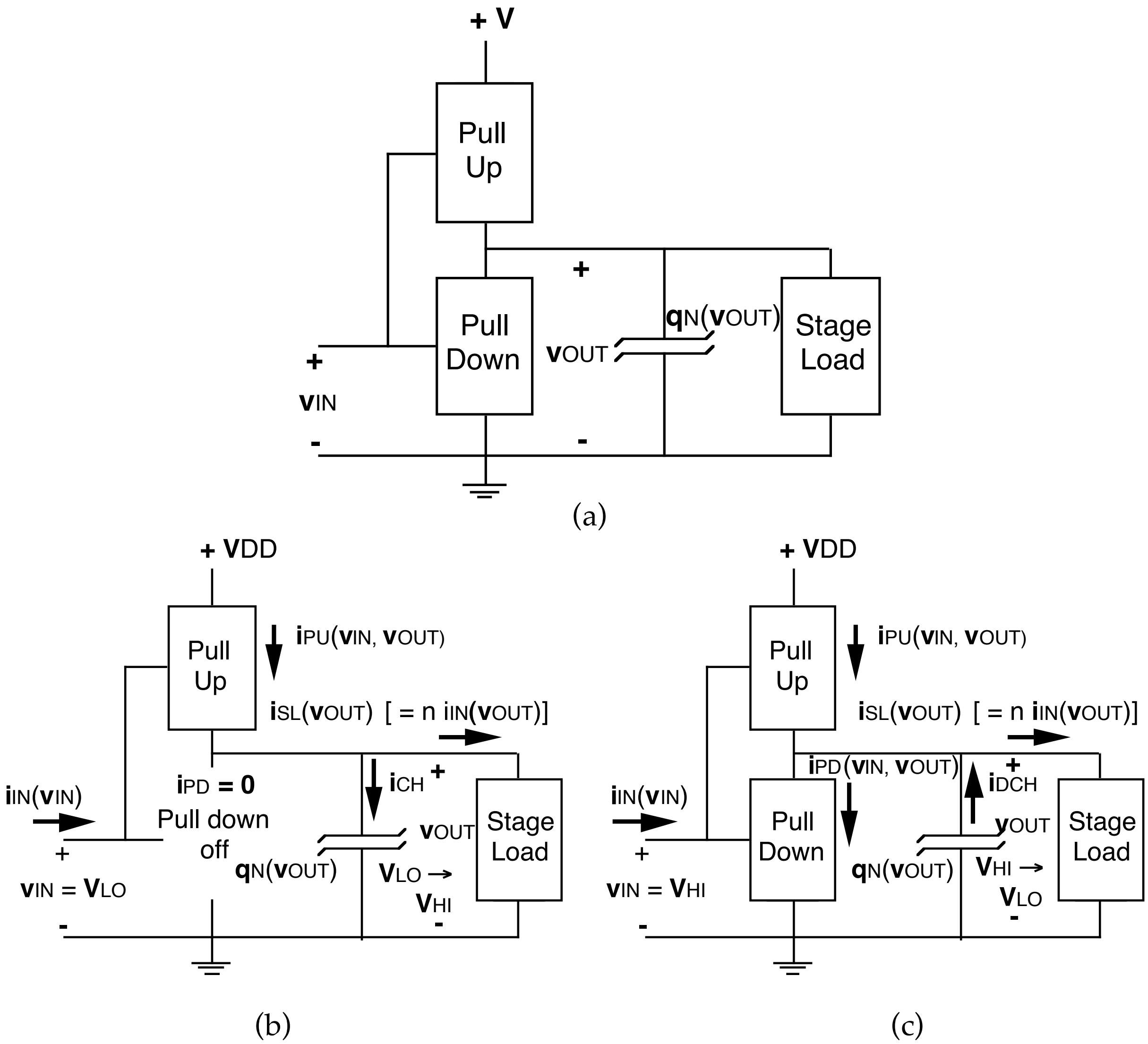
Inverter Switching Transient Analysis



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: $dq_N(v_{OUT})/dt = i_{CH}(v_{OUT})$,

and

Discharging: $dq_N(v_{OUT})/dt = i_{DCH}(v_{OUT})$.

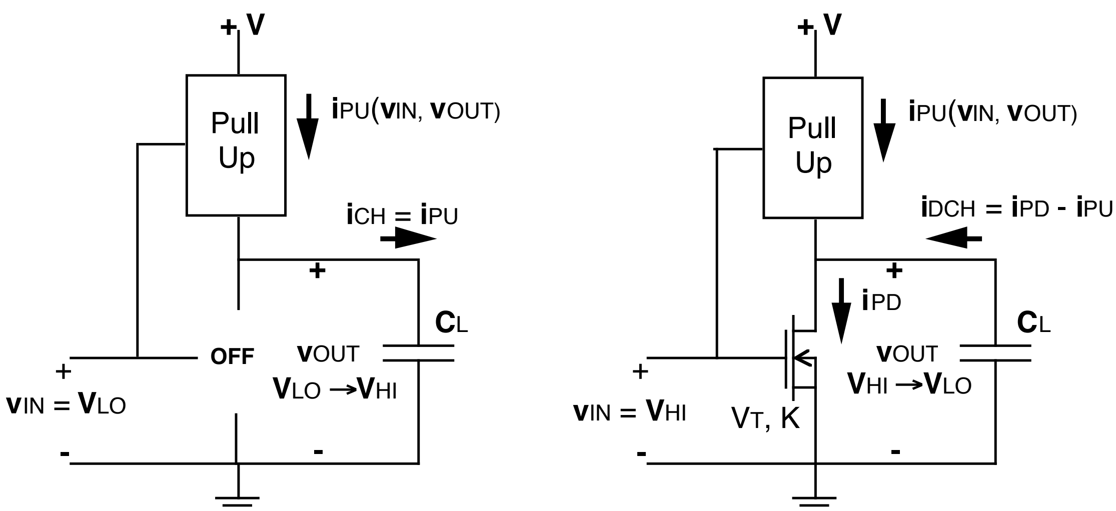
These are in general very complicated and difficult to solve by any means. If, however, the charge store can be modeled as a linear capacitor, C_L (i.e., $q_N \approx C_L v_{OUT}$), as illustrated below, then we can write,

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

and

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

These are now differential equations for $v_{OUT}(t)$ that we should at least be able to solve numerically, if we can not 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).



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

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

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

and

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

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