PROBLEM 1: VTC

In this problem we will analyze the noise margins for a chain of non-inverting gates. $V_{dd} = 2.5\text{V}$. Figure 1.b. is a VTC for all three buffers in Fig. 1.a. The VTC has four segments, with the transient region between the two flat regions that can be approximated with a second-order curve.

![Figure 1.a.](image)

![Figure 1.b.](image)

a) Add a voltage source to Figure 1.a. that you would use for modeling the noise coupling to gate $M_2$.

b) Determine the noise margins for gate $M_2$ when the noise couples to only to its input.

c) Notice that the definition of static noise margin is somewhat optimistic when there are multiple noise sources in the chain. Derive the noise margin for the case when independent noise sources couple to all nodes in the chain.

PROBLEM 2: Noise coupling

Let’s analyze the effects of capacitive coupling. Assume that there are two wires routed in close proximity driving two inverters as shown in Figure 2. The coupling capacitance is $C_1 = 50\text{fF}$. Equivalent capacitance to ground of the victim wire is $C_2 = 50\text{fF}$. Input capacitances of both inverters in figure are $25\text{fF}$. The victim wire is driven by a voltage source $V_2$ through a resistance $R = 100\text{k}\Omega$. 
a) Draw the waveform on the victim wire with \( V = 2.5V \), assuming the aggressor waveform as shown in Fig. 2 (high-to-low transition from 2.5V to 0V).

b) What is the maximum voltage level coupled to the victim wire, for the case in a)?

c) The receiving inverter is CMOS with a noise margin of 1V, and a delay of 50ps. If its output is observed 100ps after the noise coupling event, would its output logic level be correct?

d) Simulate this circuit in SPICE to confirm your answer for part a and part b.

**PROBLEM 3: Charge sharing**

In this problem we will analyze the energy balance after the charge is shared between two capacitors. Initially, one of the capacitors is charged to \( V_{DD} \), the other one is discharged and the switch is open.

a) Determine the energy stored in both capacitors before closing the switch and after closing the switch (after the system reaches steady state). How much energy has been dissipated in the resistor \( R \)?

b) (Tricky) If \( R = 0 \), what is the energy in the system before and after closing the switch.