50.002 COMPUTATIONAL STRUCTURES

INFORMATION SYSTEMS TECHNOLOGY AND DESIGN

Problem Set 2

1 VTC Plot

The behavior of a 1-input 1-output device is measured by hooking a voltage source to its input and measuring the voltage at the output for several different input voltages, resulting in the following VTC plot,

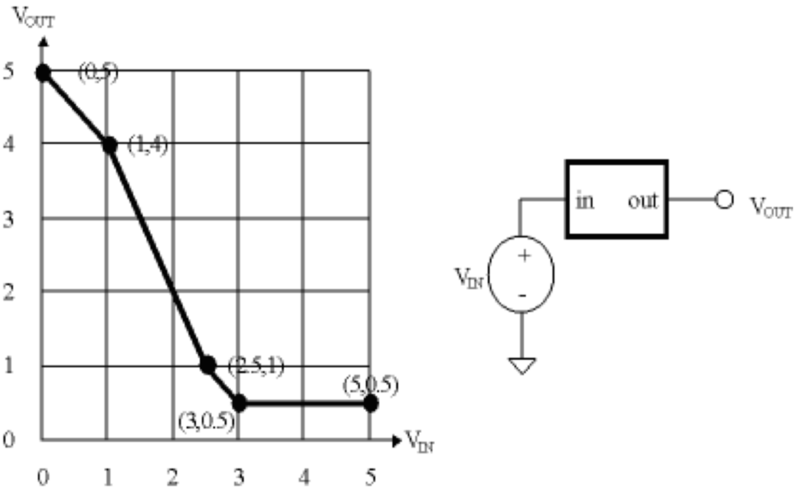

Figure 1

We're interested in whether this device can serve as a legal combinational device that obeys the **static discipline**. For this device, obeying the static discipline means that,

$$\text{If } V_{IN} \leq V_{IL} \text{ then } V_{OUT} \geq V_{OH}, \text{ and if } V_{IN} \geq V_{IH} \text{ then } V_{OUT} \leq V_{OL} \tag{1}$$

When answering the questions below, assume that all voltages are constrained to be in the range of 0V to 5V,

1. Can one choose a V_{OL} of 0V for this device? Explain.

   Solution:
   No. From the plot, it can be seen that V_{OUT} can never reach below 0.5V. If V_{OL} is chosen to be 0V, then the device doesn't satisfy the static discipline anymore.

2. What's the smallest V_{OL} one can choose and still the device obey the static discipline?

   Solution:
   0.5V. That is the lowest amount of V_{OUT} that the device can produce.

3. Assuming that we want to have 0.5V noise margins for both "0" and "1" values, what are the appropriate voltage levels for V_{OL}, V_{IL}, V_{IH}, and V_{OH} so that the device obeys the static discipline? *Hint: there are many choices. Just choose the one that obeys the static discipline and the NM constraint*.

   Solution:
   We can choose $V_{OL} = 0.5V$ from the graph, since the device is capable of producing such low voltage. With NM of 0.5V, that means that $V_{IL} = V_{OL} + 0.5V = 1V$. From the graph, we can also choose $V_{OH} = 4V$, as the part with the highest gain in the middle of the graph can most probably be the forbidden zone. Therefore, $V_{IH} = V_{OH} - 0.5V. = 3.5V$.

4. What device is this called?

   Solution:
   This device is an inverter, since a high input produces a low output and vice versa.

2 Inverter Madness

1. The following graph plots the VTC for a device with one input and one output. Can this device be used as a combinational device in logic family with 0.75 noise margins?

   Solution:
   No. This device gain is ≤ 1, hence it cannot be used as a combinational device.

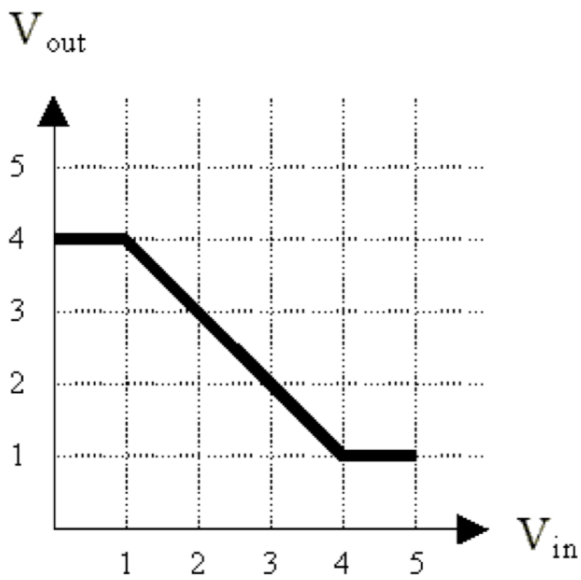

Figure 2

2. You are designing a new logic family and trying to decide on values of the four parameters: V_{OL}, V_{IL}, V_{IH}, and V_{OH} that lead to non-zero noise margins for various possible inverter designs. Four proposed inverter designs exhibit the VTC shown in the diagrams below. For each design, either specify four suitable values of V_{OL}, V_{IL}, V_{IH}, and V_{OH} or explain why no values can obey the static discipline.
Hint: you may want to start by choosing NM to be 0.5V for ease of calculation.

Solution:
(B) and (C) cannot be used as inverter (combinational device) as its gain is ≤ 1.
For (A), choose NM = 0.5V, then $V_{OL} = 1V$, $V_{IL} = 1.5V$, $V_{IH} = 5V$, and $V_{OH} = 5.5V$.
For (D), choose NM = 0.5V, then $V_{OL} = 0.5V$, $V_{IL} = 1V$, $V_{IH} = 5$, and $V_{OH} = 5.5V$.

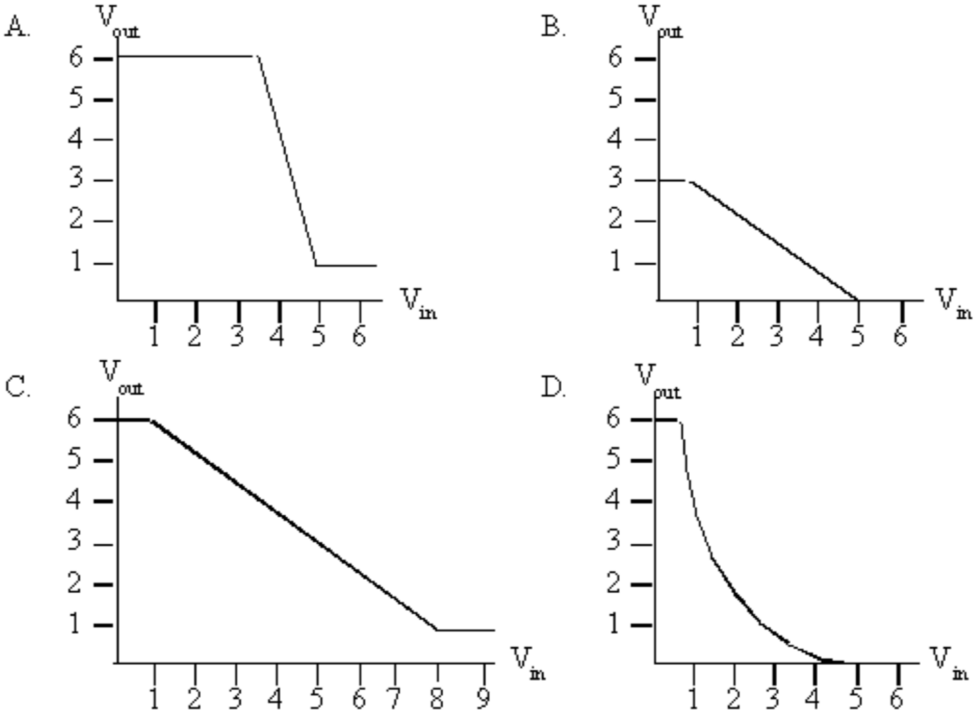

Figure 3

3 Static Discipline

1. Consider a combinational *buffer* with one input and one output. Suppose we set its input to some voltage V_{IN}, wait for the device to reach a steady state, then measure the voltage on its output V_{OUT} and find out $V_{OUT} < V_{OL}$. What can we say about V_{IN}?

   Solution:
   We have a valid *low* output, but that doesnt mean that we have a valid *low* input. However we know for sure that input cannot be higher than V_{IH} because static discipline requires the output to be higher than V_{OH} if this is the case for a buffer. Hence, the only thing we can infer is that $V_{IN} < V_{IH}$ (means input voltage is either a valid low or an invalid value).

2. Now consider an inverter. Suppose we set its input to some voltage V_{IN}, wait for the device to reach a steady state, then measure the voltage on its output V_{OUT}, and find $V_{OUT} > V_{OH}$. What can we say about V_{IN}?

   Solution:
   We have a valid *high* output, but that doesnt mean that we have a valid *low* input. **Static discipline** states that *given a valid input, the device is always able to give a valid output*, but it does not mean that the reverse is true, i.e: invalid

input does NOT have to give out invalid output.

However we know for sure that input cannot be higher than V_{IH} because static discipline requires the output to be lower than V_{OH} if this is the case for an inverter. Hence, the only thing we can infer is that $V_{IN} < V_{IH}$ (means input voltage is either a valid low or an invalid value).

4 VTC Analysis

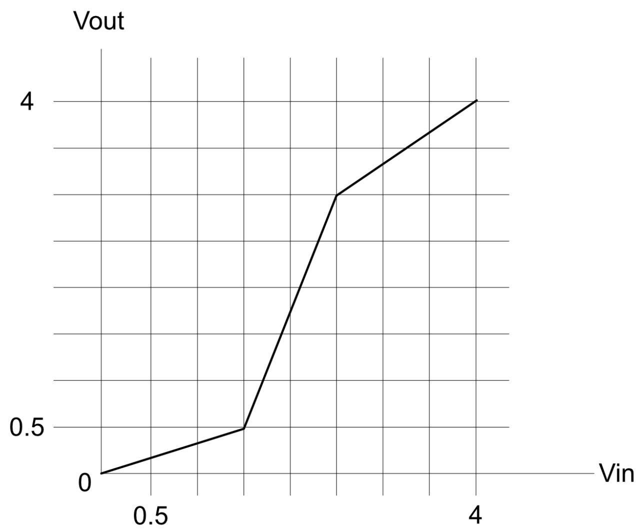

Figure 4: VTC Plot

Which of the following specification(s) does not obey the static discipline? Select all that apply.

1. $V_{IL} = 0.4V, V_{IH} = 3.1V, V_{OL} = 0.2V, V_{OH} = 4.2V$
2. $V_{IL} = 0.5V, V_{IH} = 3V, V_{OL} = 0.3V, V_{OH} = 4V$
3. $V_{IL} = 0.2V, V_{IH} = 3V, V_{OL} = 0.4V, V_{OH} = 4.2V$
4. $V_{IL} = 0.5V, V_{IH} = 4V, V_{OL} = 0V, V_{OH} = 3.5V$
5. $V_{IL} = 0.5V, V_{IH} = 3.5V, V_{OL} = 0V, V_{OH} = 4V$

Solution:
All does **not** obey the static discipline. You may easily check whether the device is able to provide the prescribed V_{OH} given a corresponding V_{IH} in the options, and whether it is able to provide as well the given V_{OL} given a coresponding V_{IL} in the options from tracing the graph.