50.002 Computational Structures

Information Systems Technology and Design

The Digital Abstraction

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1 The Digital Abstraction

In digital abstraction, we encode information in terms of 0s and 1s. The counterpart for digital abstraction is analog (continuous). Why do we want digital abstraction?

1. It allows us to encode information
2. In a cheap and stable way
3. We can manipulate it easily

We encode information using **voltages**, stored in **semiconductors (MOSFET)**. **Pros**: ease of generation, zero power in steady-state. **Cons:** Easily affected by external disturbances, can change easily.

2 Voltage to encode information

We can use 'low' voltage to encode '0' and 'high' voltage to encode '1', and define the low and high threshold for each valid '0' and '1'. Anything that is between the low and high threshold value is called the **forbidden zone**.

3 Combinational Device

A device that has four things:

1. Inputs,
2. Outputs,
3. Functional specification that details the output for each input
4. The propagation time to get a valid output given a valid input

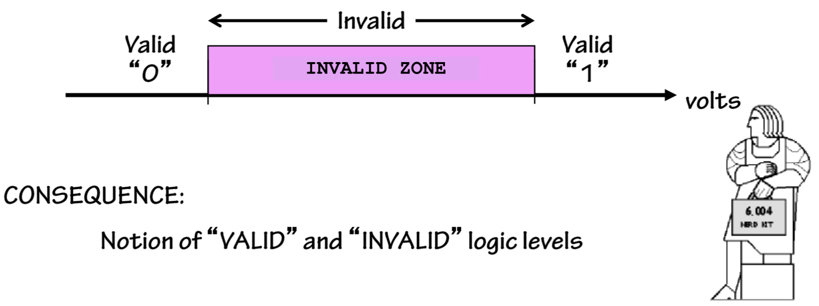

Figure 1

4 The Static Discipline

It is one of the contracts in system design. It is a guaranteed behavior for each processing block in a system. This is necessary so that the system has a predictable behavior.

The static discipline is : **If a system is given a valid input, then it guarantees that it will give a valid output**.

5 Noise Margin (NM)

The problem is that a wire, that connects two or more combinational devices together do not obey static discipline. It has noise. Hence, we need the NM.

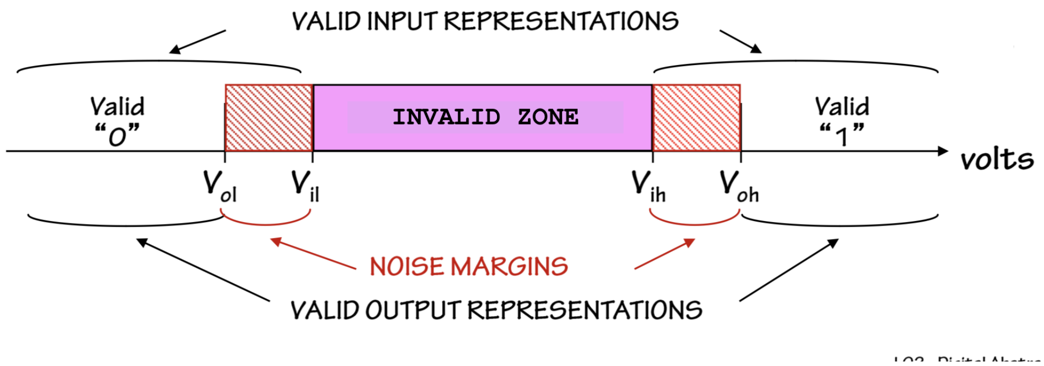

Figure 2

Things to note:

1. V_{ol} or V_{oh} is the voltage that **your system** outputs, depending on whether its '0' or '1'. It is going to be received by another system after traversing through some wire.

2. V_{ih} or V_{ih} is the voltage that **your system** receive as input from another system.

3. Wire has noise, it can cause voltages to change as it traverse through it

4. So V_{ol} is lower than V_{il}, because we would want to be more relaxed, meaning that we can receive a not-so-low '0' input voltage because we understand that there's noise along the wires. However, we are strict with our own system and produce a strictly-valid-low '0' output voltage so that when it reaches the other system it will still be a valid '0' despite wire disturbances.

6 Voltage Transfer Characteristic (VTC)

The VTC plots input voltage (V_{in}) to your system vs the output voltage (V_{out}) from your system. It **does not** tell us how fast the device is. It just captures the static behavior and tells us what kind of device it is. The image below shows the VTC of a buffer. The red zone is the **forbidden zone**.

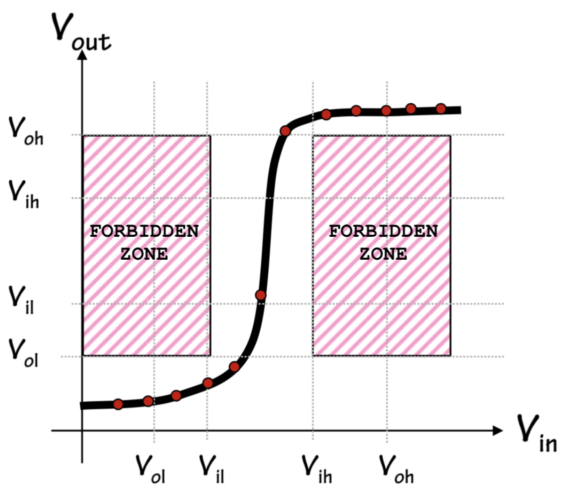

Figure 3

A combinational device's VTC has::

1. Gain > 1 ($\delta V_{out}/\delta V_{in}$), because of static discipline,

$$Gain = \frac{\delta V_{out}}{\delta V_{in}} = \frac{V_{oh} - V_{ol}}{V_{ih} - V_{il}} \tag{1}$$

   If Gain > 1, then there is a finite, positive noise margin. If Gain = 1, then there's zero noise margin. It is impossible to have Gain < 1.

   Also, having positive gain maintains the **amplitude** passed through the system as signal loss is inevitable through the system.

2. Non-linear gain