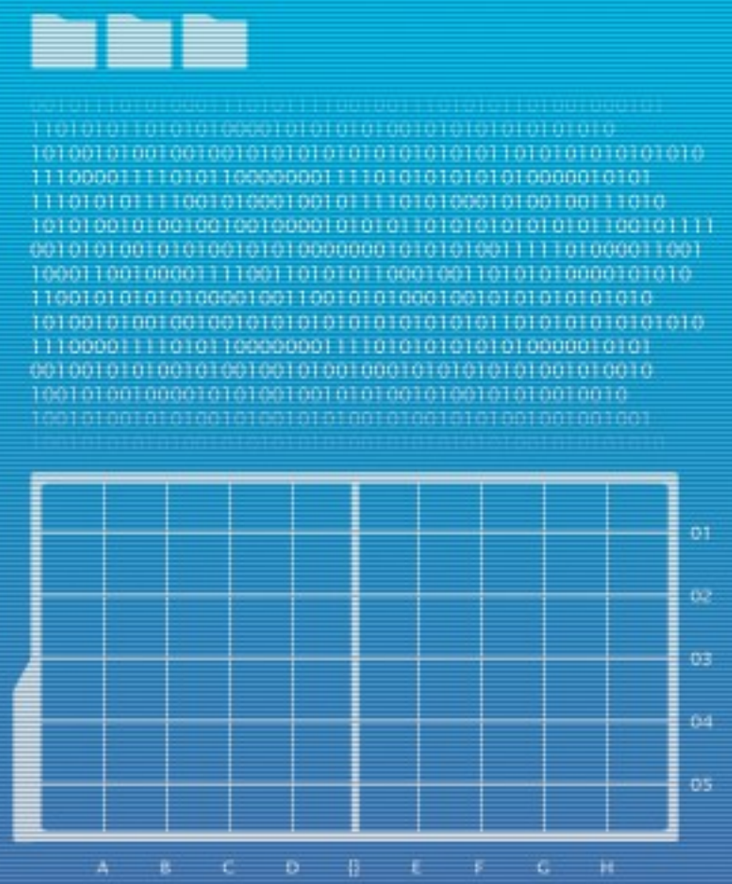
DEPARTMENT OF
INFORMATION SYSTEMS
AND COMPUTER SCIENCE

The Digital Deal and Static Discipline

How to Handle Noise



Lecture Time!

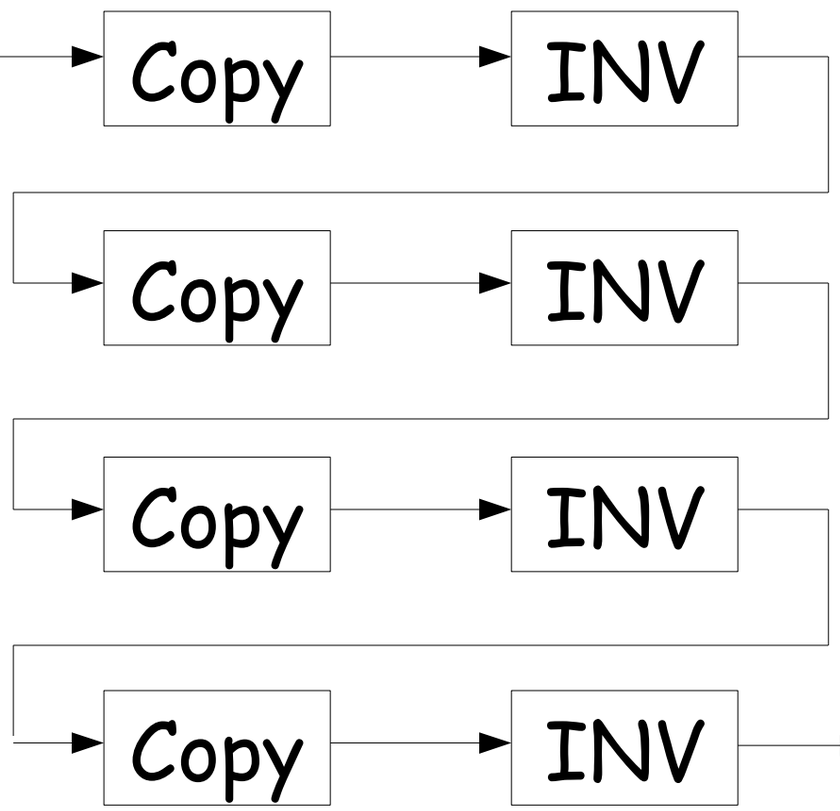
- Noise: Live With It
- Digital: Compared to Analog
- Static Discipline: Compensating for Noise

TV Snow

- Step 1: Make sure you receive your television signal from the airwaves (using an antenna) instead of cable.
- Step 2: Look closely, or simply fiddle with the antenna, or change to a non-existent channel.
- Step 3: Notice the “fuzzy” picture and sound?
  - This phenomenon is called (electronic) noise, which is somewhat similar to friction; it’s always there and it could cause potential problems.
    - Even with cable, the problem is still there, but not as much.

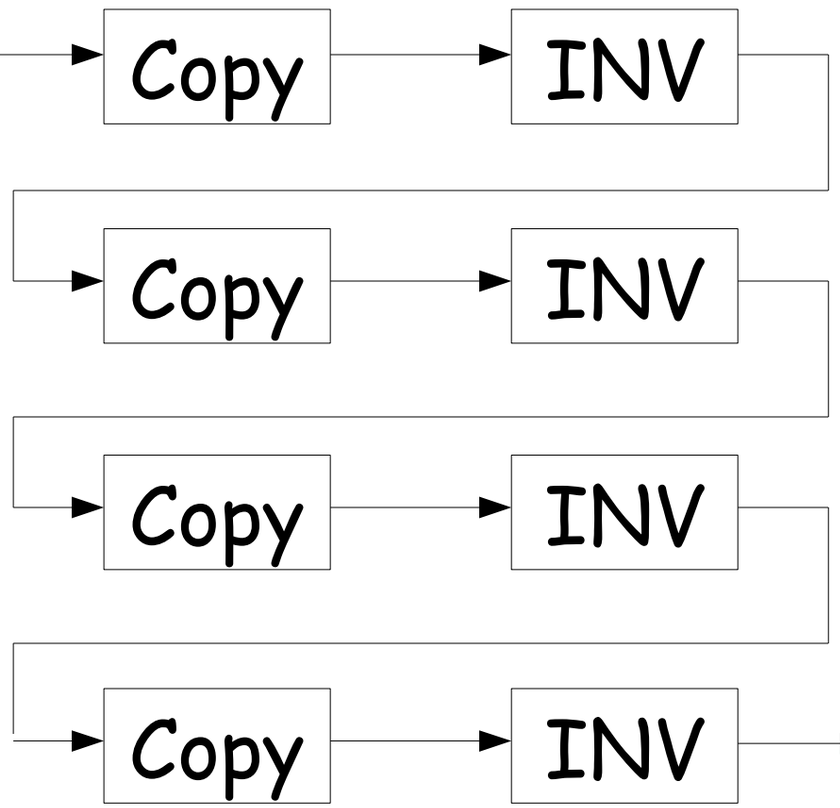
The Ideal World

- Easy contracts should not be hard to fulfill:



The Real World

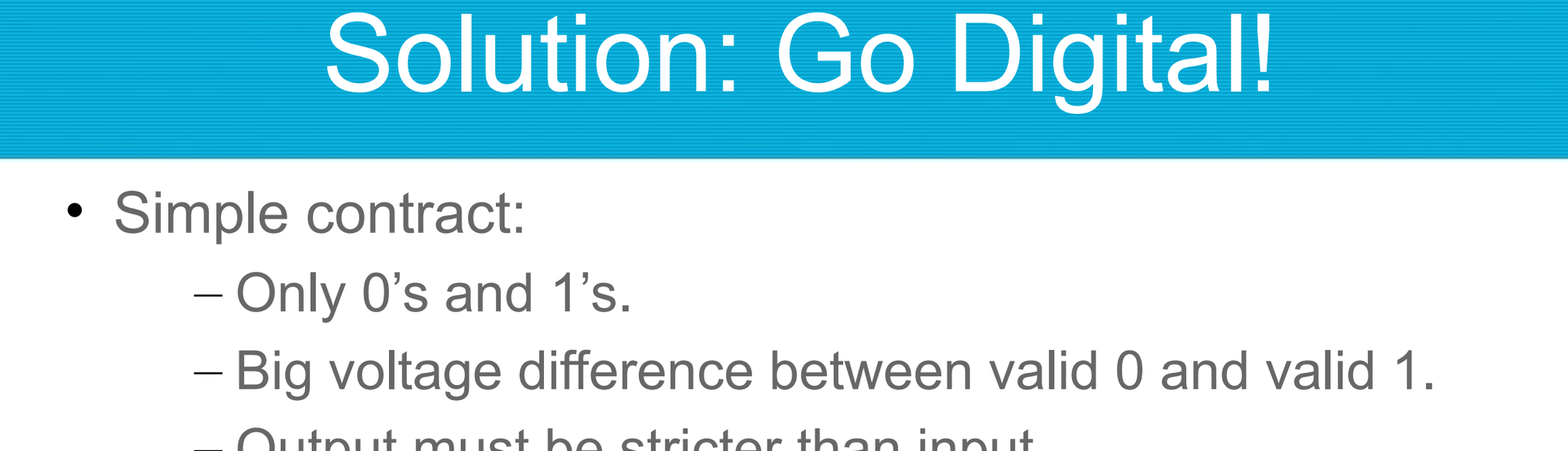
- Even 10mV noise can ruin results, especially if there are multiple stages!



- This is why we say computation is the <u>reliable</u> processing of information.

Solution: Go Digital!

- Simple contract:
  - Only 0's and 1's.
  - Big voltage difference between valid 0 and valid 1.
  - Output must be stricter than input.
- We can't transmit as much information in the same time as analog, but we get a guarantee of reliable processing.



The Digital Abstraction

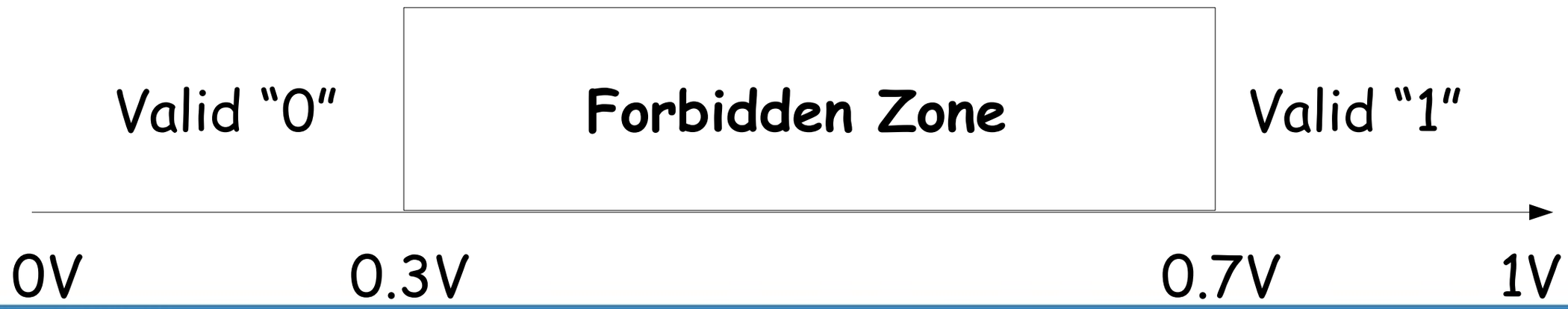
- By limiting our abstractions to handling only 0's and 1's, we make it easier to implement them in the real world.

Real World: ANY physical medium is subject to friction, flaws, and noise.

"Ideal" Abstract World:
Only 0's and 1's.
Noise-resistant?

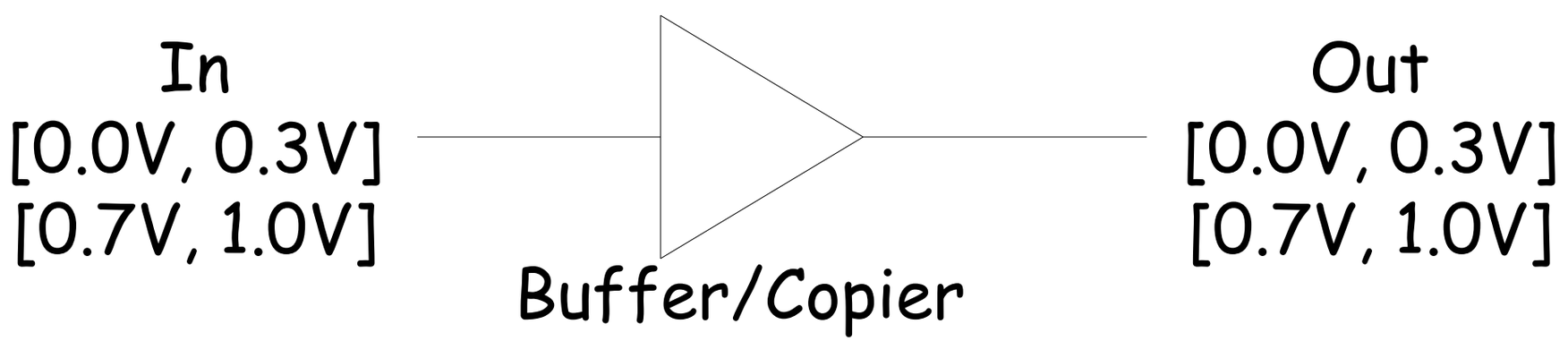
The Digital Deal (Part 1)

- Goal: Do not mistake “0” for “1”, or vice versa.
  - We want large noise margins.
- Therefore:
  - Define range for “valid 0” and “valid 1”.
  - Anything in-between is “invalid” (not considered 1 or 0).
  - Keep large “forbidden zone”.
- Example (assuming a range of 0V-1V) :



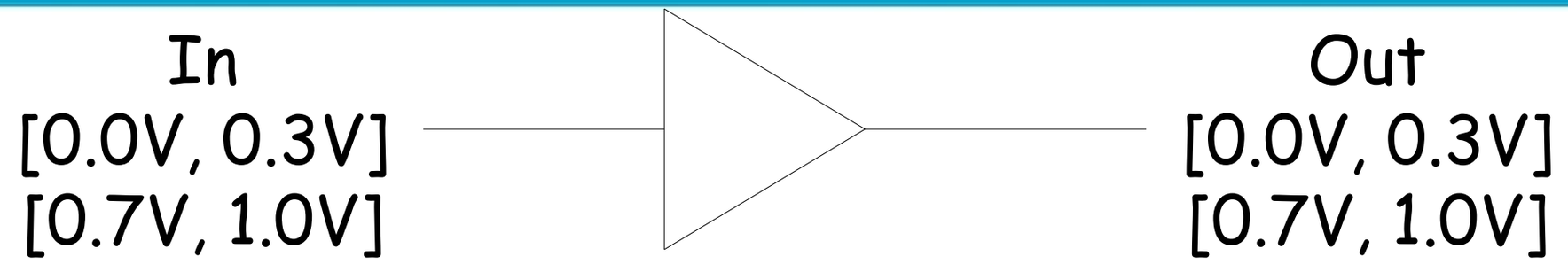
Static Discipline

- The static discipline is a simple rule:
  Valid inputs must generate valid outputs.
  - A combinational device obeys the static discipline.

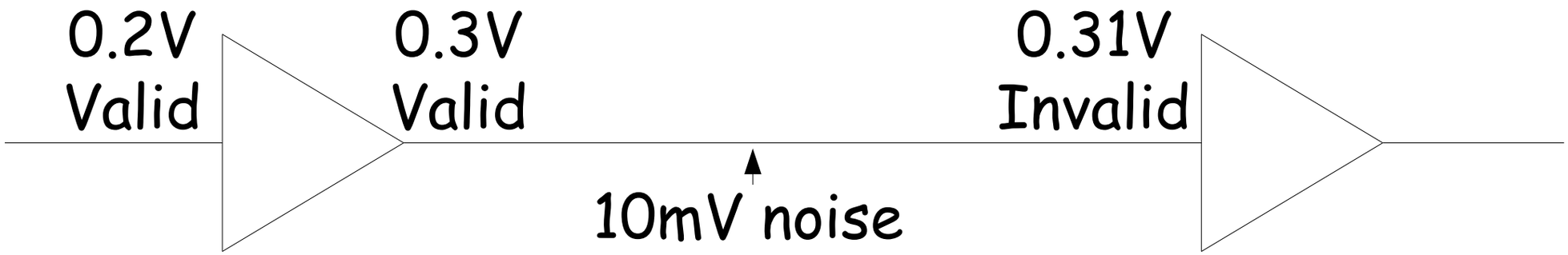


- Nice property: Every acyclic circuit whose components are combinational devices is itself a combinational device.
  - In other words, combinational devices can be chained into infinitely large devices without noise contamination!

Can't I Just Use a Wire?



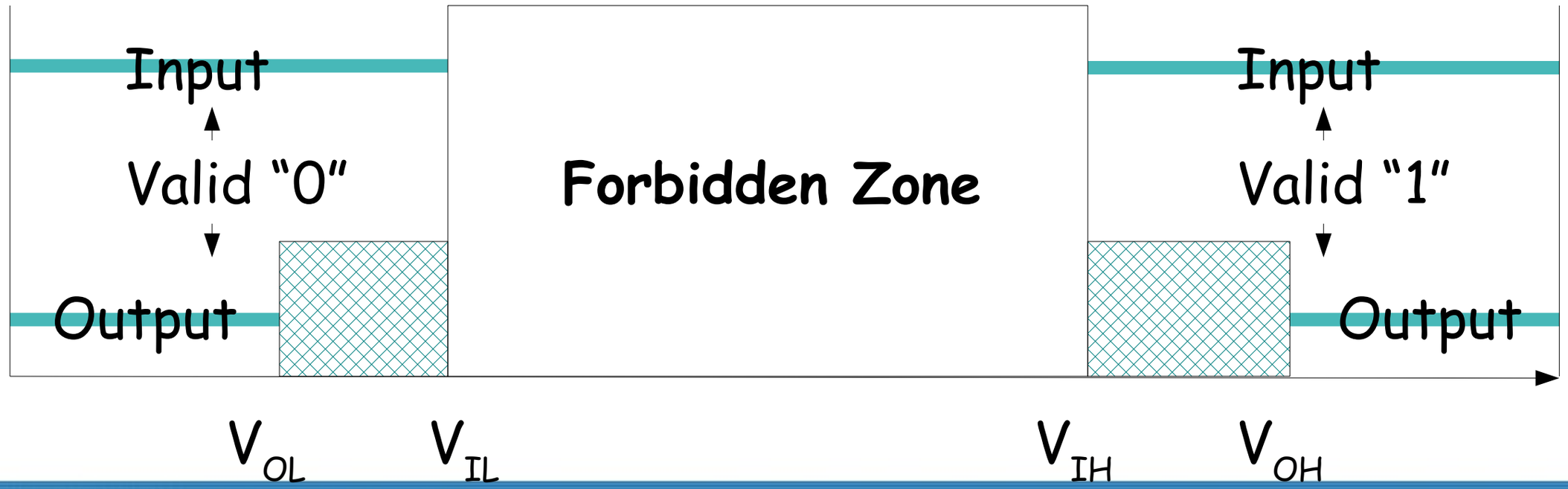
- Something is still wrong... What if we chain 2 buffers?



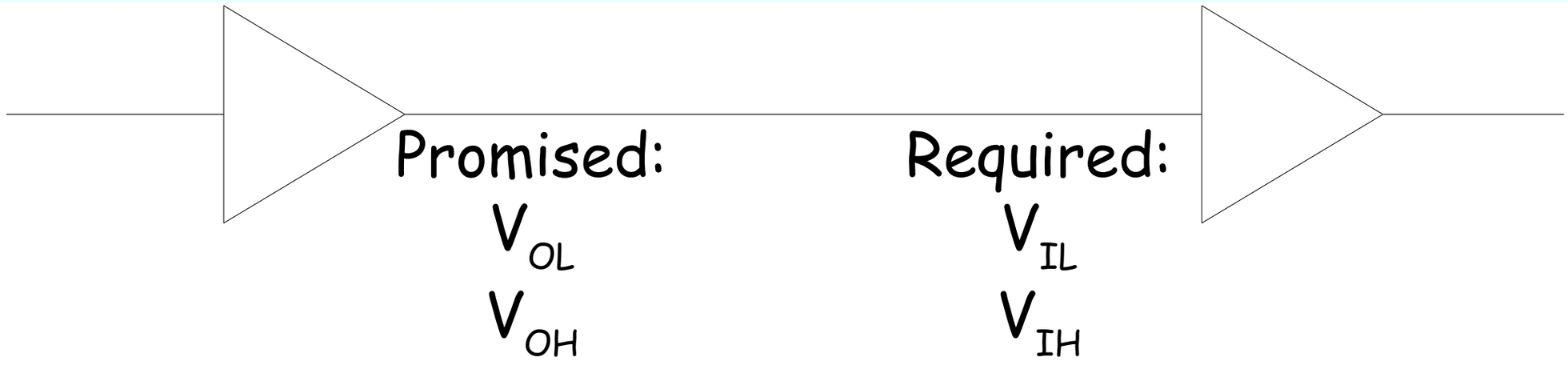
- Static discipline is violated!
  - Invalid output for valid input!
    - The first buffer still outputted 0.31V, as far as we're concerned.

The Digital Deal (Part 2)

- Output constraints must be tighter!
  - Output must “clean up” input signals that are “dirty”.
  - Combinational devices undo or minimize the effects of noise, as long as noise levels aren't too high.



Enforcing the Static Discipline



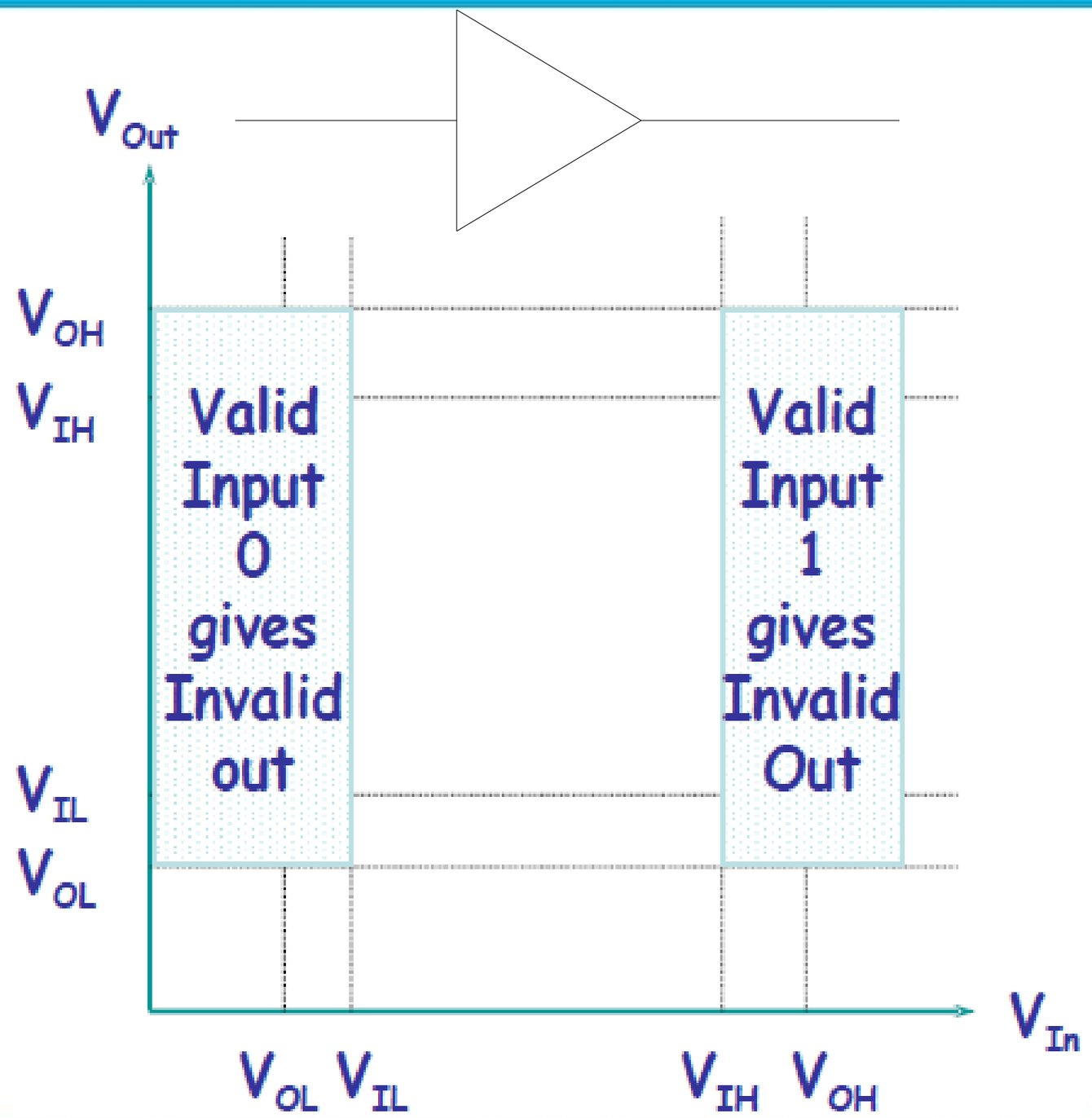
- V_{OL} = *Highest* voltage which may be output as valid “0”
- V_{OH} = *Lowest* voltage which may be output as valid “1”
- Low noise margin = $V_{IL} - V_{OL}$

- V_{IL} = *Highest* voltage which must be interpreted as valid “0”
- V_{IH} = *Lowest* voltage which must be interpreted as valid “1”
- High noise margin = $V_{OH} - V_{IH}$

- Static Discipline: Noise Margins > 0
  $V_{OL} < V_{IL} < V_{IH} < V_{OH}$

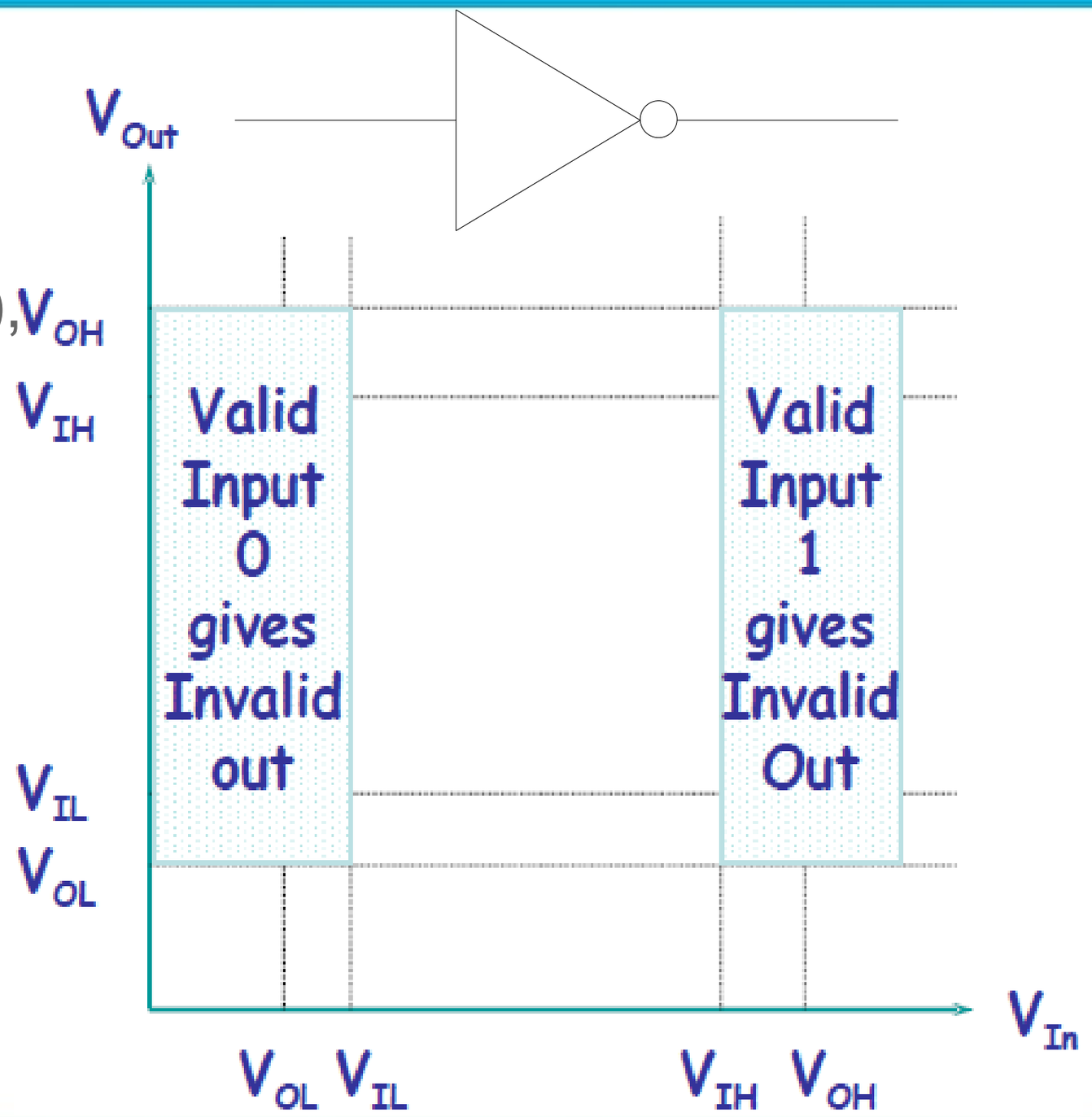
Voltage Transfer Curve

- Checking if a device obeys the static discipline can also be done visually.
  - VTC plot must not intersect labeled boxes.
  - Let's plot some imaginary VTCs for a buffer and see if they work.



Voltage Transfer Curve

- Observation: For the device to obey the static discipline (and therefore work), we need:
  - Nonlinearity
  - Gain
- Let's plot some imaginary VTCs again, this time for an inverter.



Gain and Nonlinearity

- Nonlinearity
  - Not a straight y=kx line.
  - Curve is flatter for valid inputs.
  - Noise is “flattened”.
  - Outputs from slightly dirty valid inputs are slightly different, but are still valid.
- Gain
  - If curve is flat in some areas, then it has to “catch-up” in the middle.
  - Implies that we have amplification in middle part.
- Gain and nonlinearity *make it possible* to restore “dirty” inputs into “clean” outputs!

Technologies for Computation

- It is IMPOSSIBLE to implement reliable computation without nonlinearity and gain.
  - Otherwise, noise will propagate.
- ANY physical device that has nonlinearity and gain has potential to be used for computation.
  - Mechanical devices
  - DNA computing
  - Quantum devices
- Form of nonlinearity to look for: A SWITCH
  - Turn OFF or ON based on input
  - Short transition means there is gain and nonlinearity.
  - If we can make a switch, we can do computing!