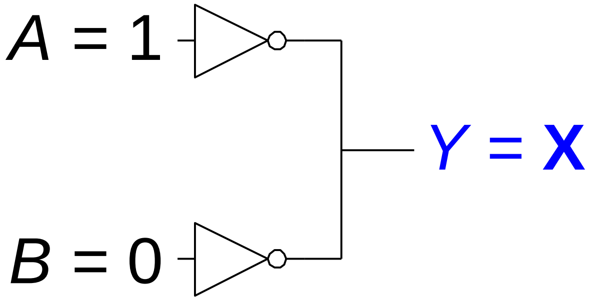
Problems and (some) Solutions

Contention: X

- Contention: circuit tries to drive the output to 1 and 0
  - Actual value may be somewhere in between
  - Could be a legal 0, a legal 1, or in the forbidden zone
  - Might change with voltage, temperature, time, noise
  - Often causes excessive power dissipation

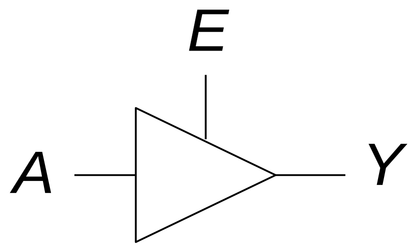


- Contention usually indicates a bug.
  - Fix it unless you are sure you know what you are doing.
- Warning: X is used for "don't care" and contention
  - Note the same thing
  - Look at the context to tell them apart

Floating: Z

- Floating, high impedance, open, high Z
- Floating output might be 0, 1, or somewhere in between
  - A voltmeter won't indicate whether a node is floating

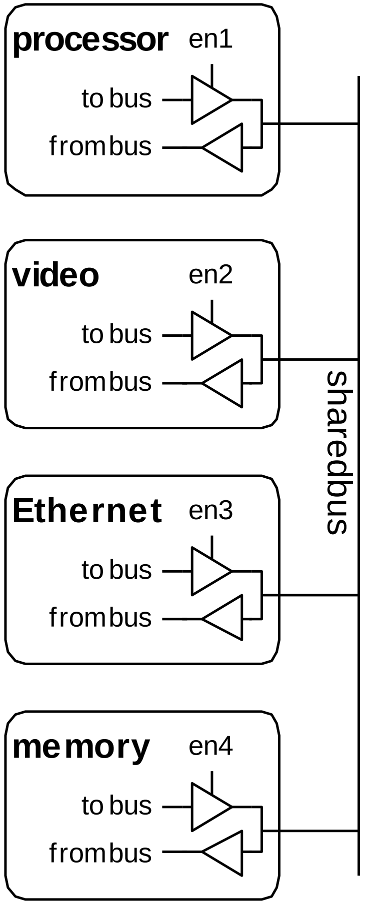
Tristate Buffer



E	A	Y
0	0	Z
0	1	Z
1	0	0
1	1	1

Tristate Busses

- Floating nodes are used in tristate busses
  - Many different drivers
  - Exactly one is active at any time

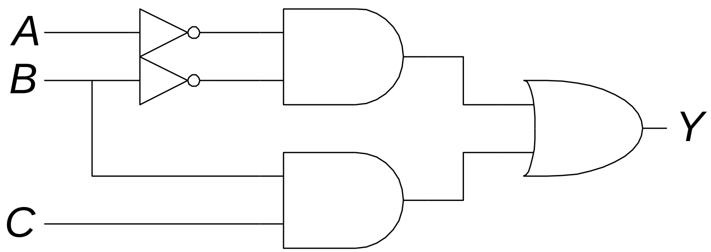


Glitches

- Glitch: when a single input change causes multiple output changes
- Glitches don’t cause problems because of synchronous design conventions
- But it’s important to recognize a glitch when you see one in timing diagrams

Glitch Example

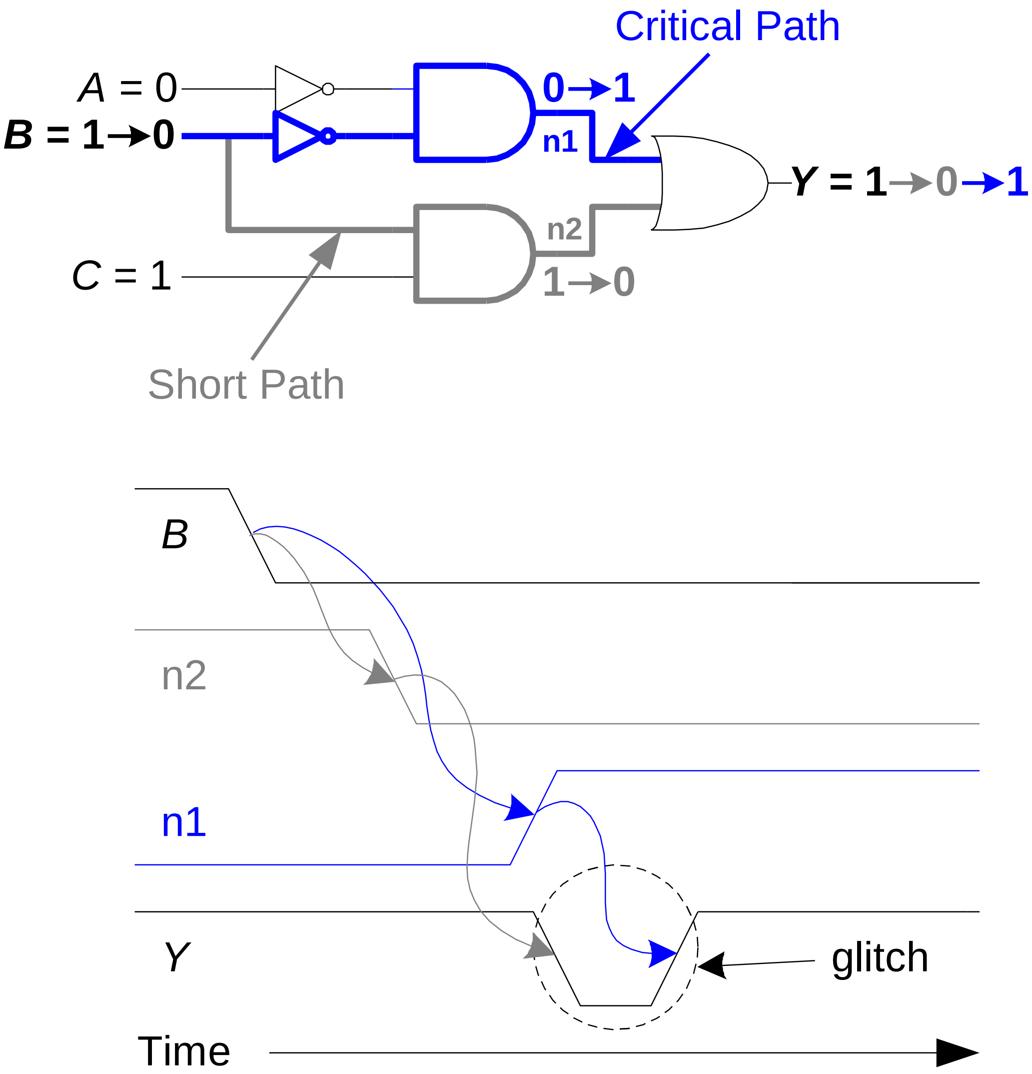
- What happens when A = 0, C = 1, B falls?



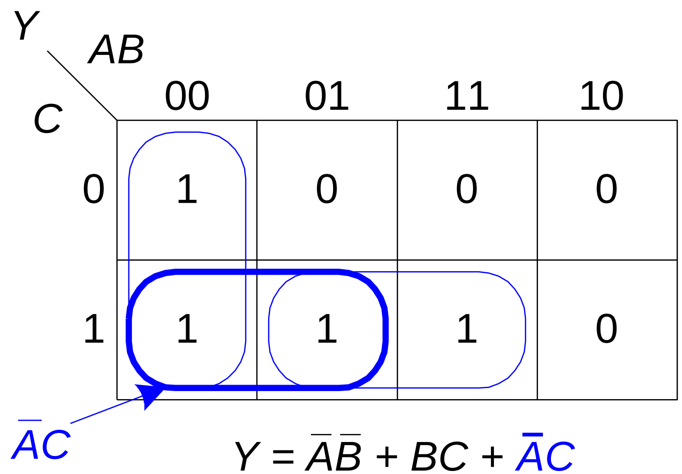
Y: C \ AB	00	01	11	10
0	1	0	0	0
1	1	1	1	0

$$Y = \overline{A}\,\overline{B} + BC$$

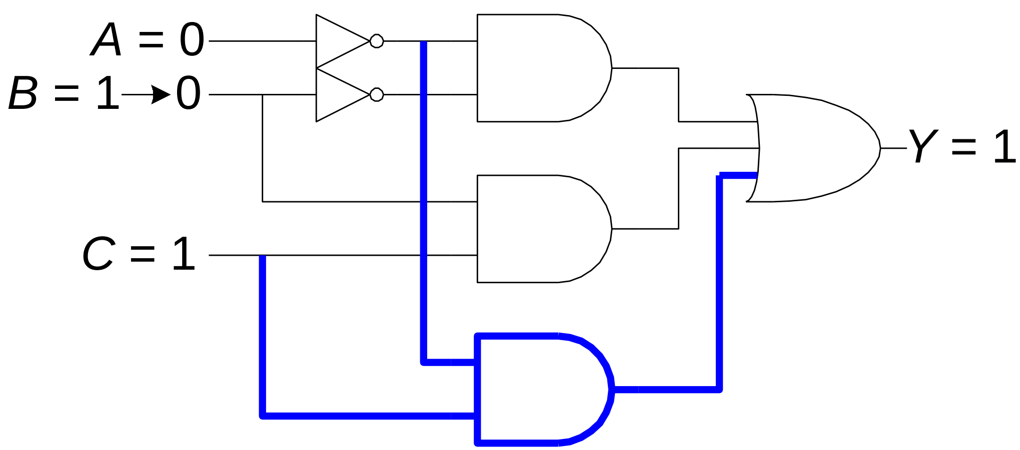
Glitch Example (cont.)



Fixing the Glitch



$Y = \bar{A}\bar{B} + BC + \bar{A}C$

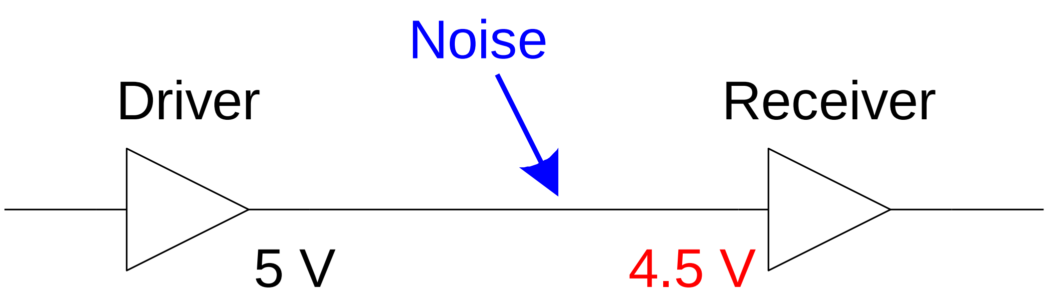


Why Understand Glitches?

- Glitches don’t cause problems because of synchronous design conventions
- But it’s important to recognize a glitch when you see one in simulations or on an oscilloscope
- Can’t get rid of all glitches – simultaneous transitions on multiple inputs can also cause glitches

What is Noise?

- **Anything that degrades the signal**
  - E.g., resistance, power supply noise, coupling to neighboring wires, etc.
- **Example:** a gate (driver) could output a 5 volt signal but, because of resistance in a long wire, the signal could arrive at the receiver with a degraded value, for example, 4.5 volts

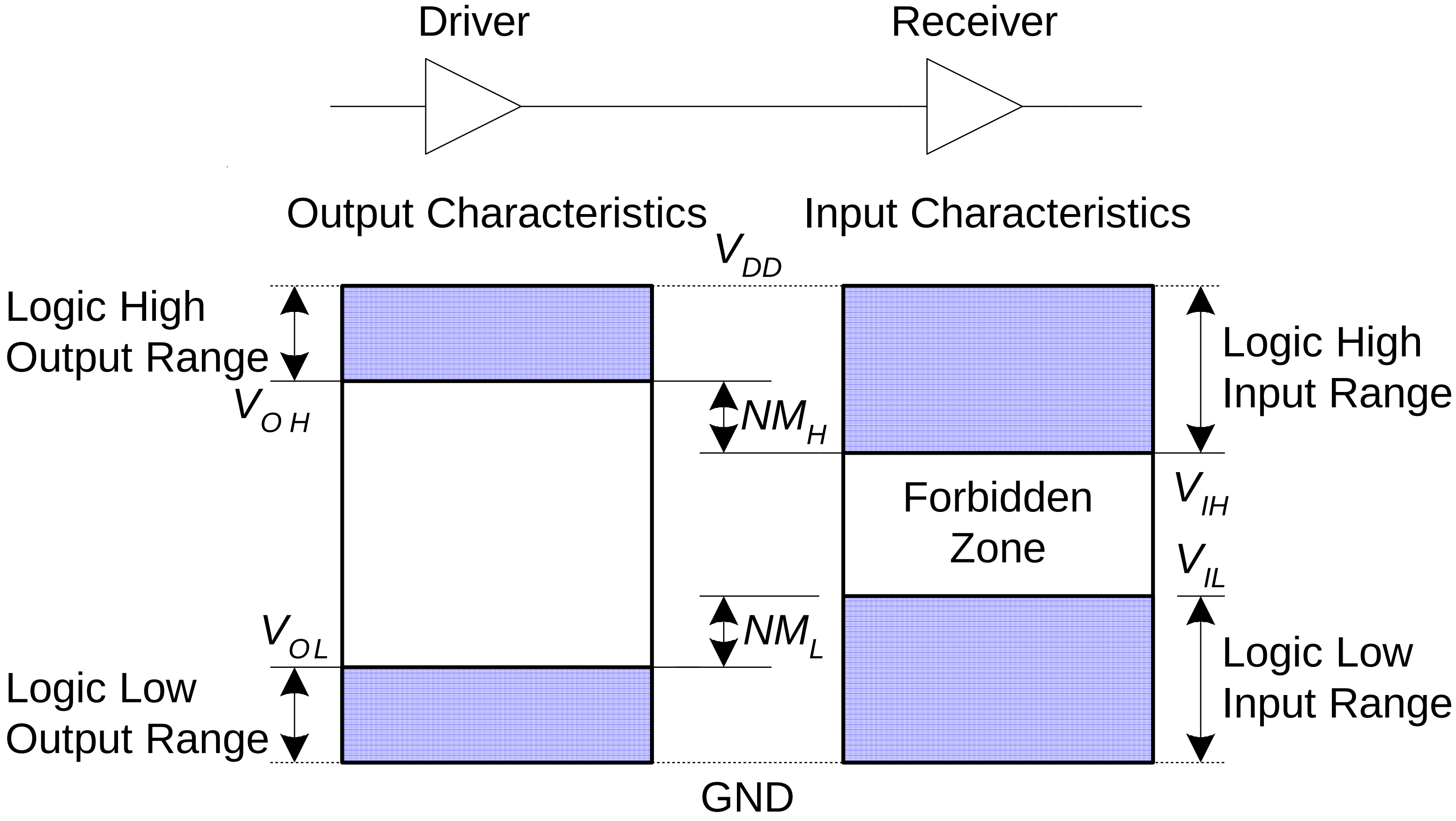


The Static Discipline

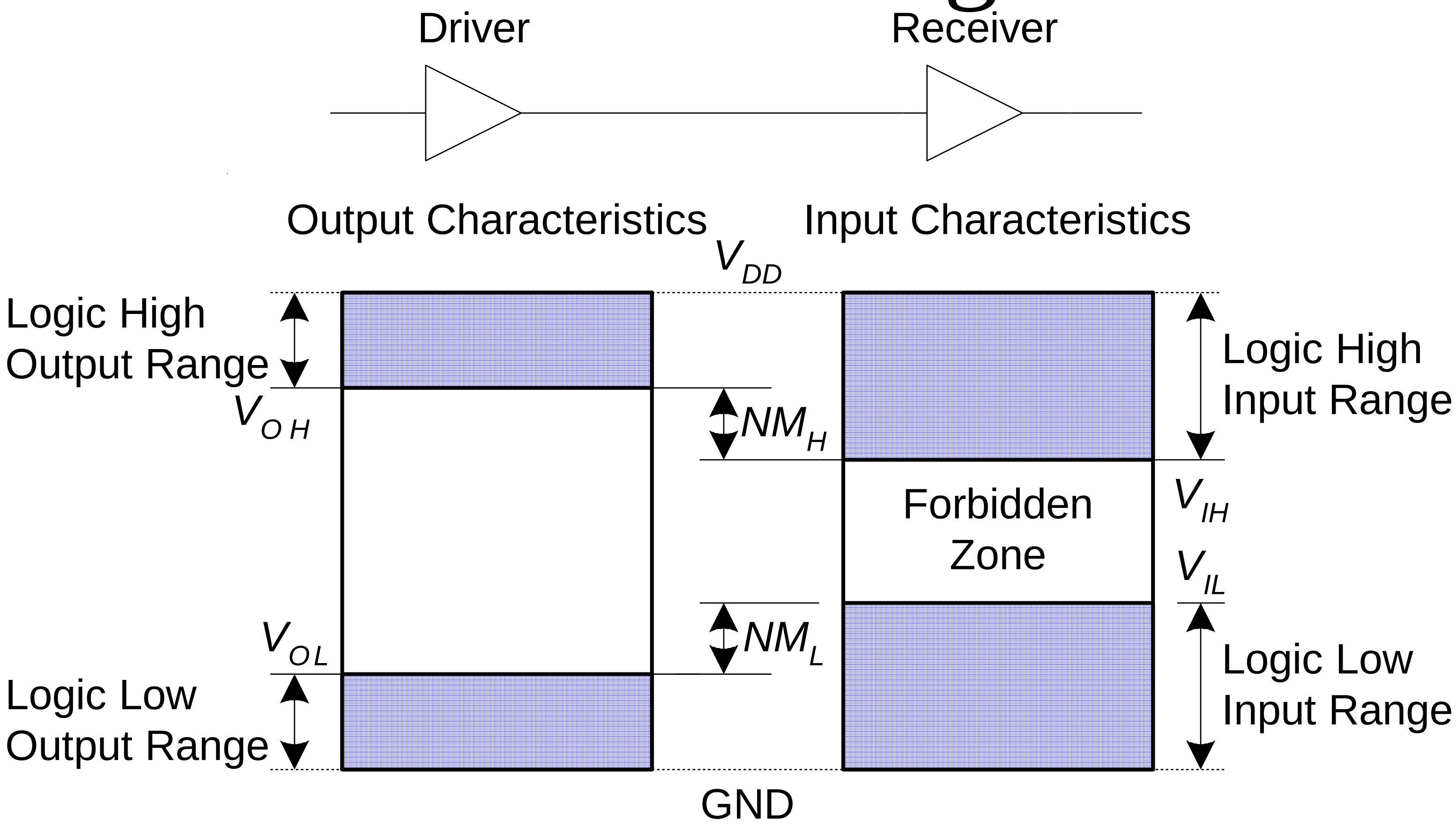
- Given logically valid inputs, every circuit element must produce logically valid outputs

- Discipline ourselves to use limited ranges of voltages to represent discrete values

Logic Levels



Noise Margins

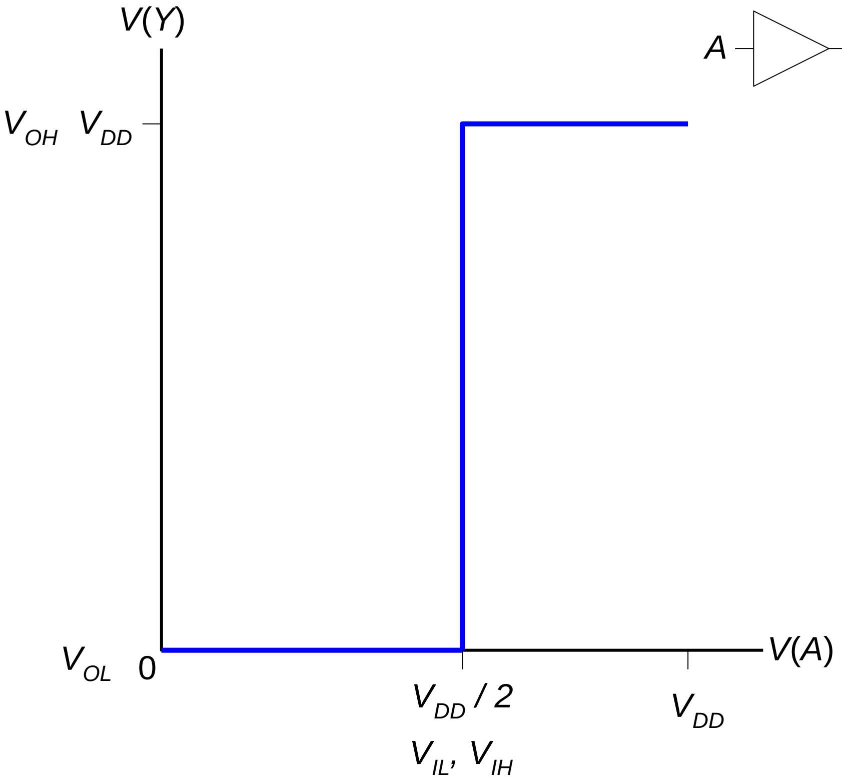


$$NM_H = V_{OH} - V_{IH}$$

$$NM_L = V_{IL} - V_{OL}$$

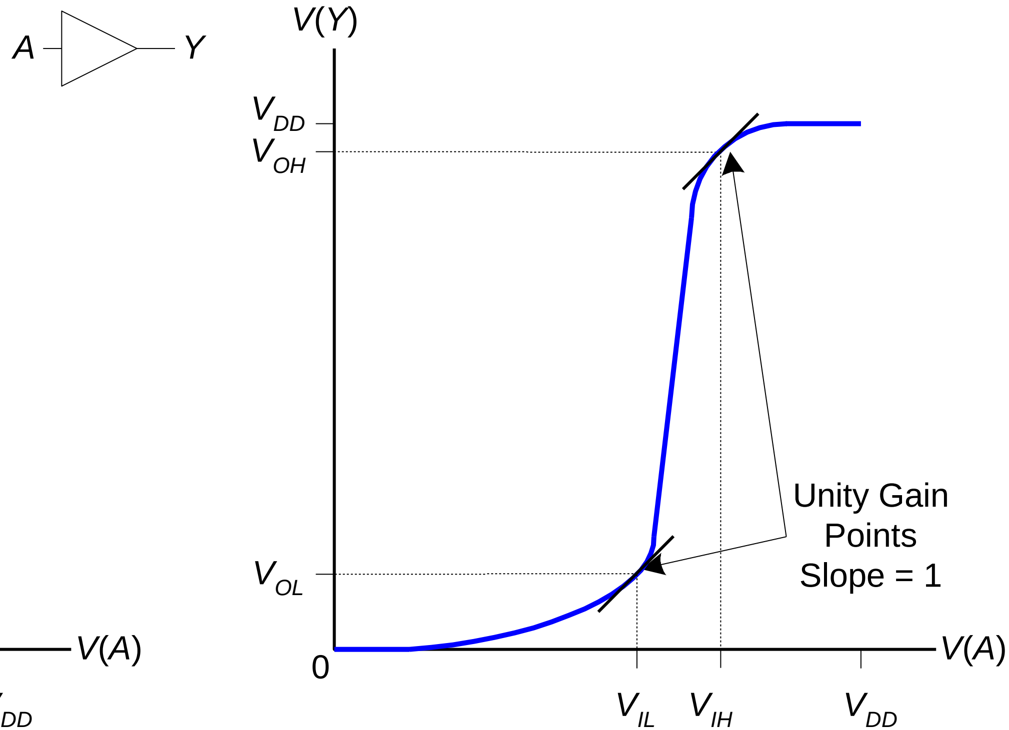
DC Transfer Characteristics

Ideal Buffer:



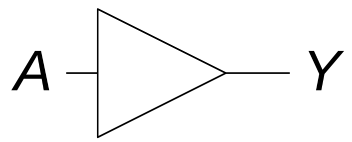
$NM_H = NM_L = V_{DD}/2$

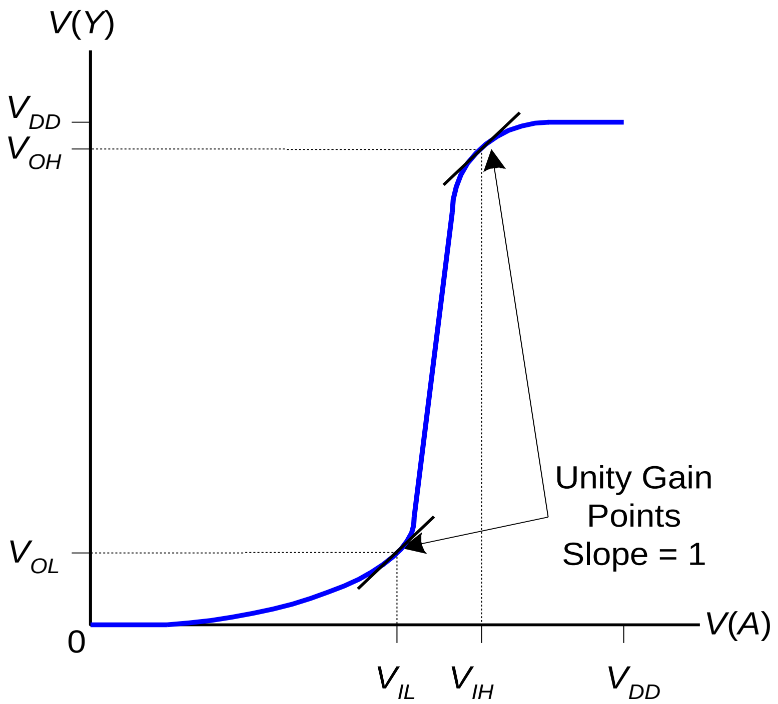
Real Buffer:

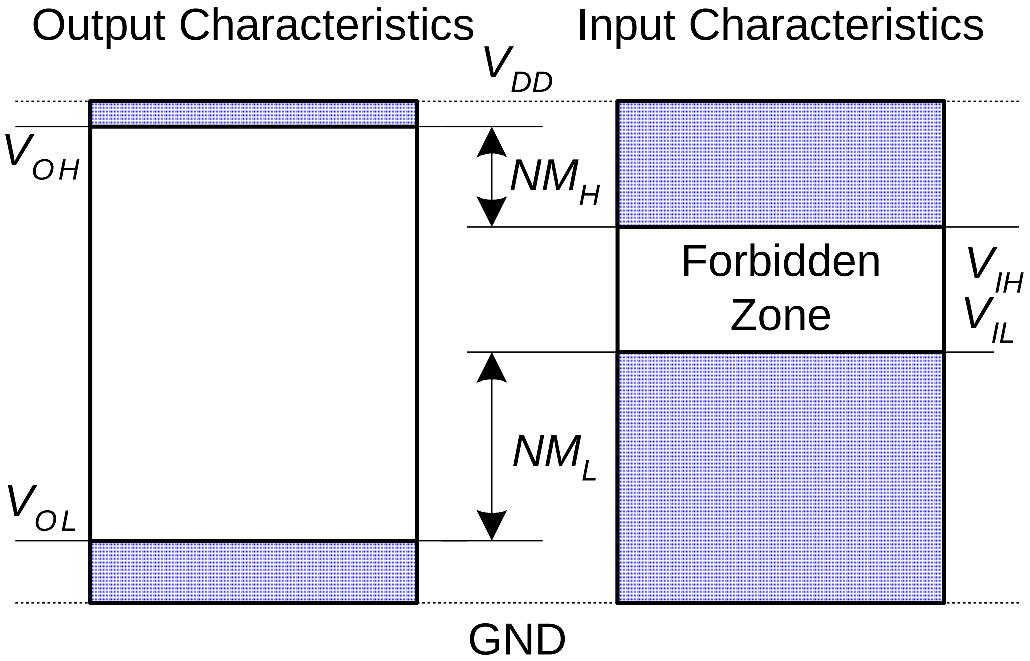


$NM_H, NM_L < V_{DD}/2$

DC Transfer Characteristics







V_{DD} Scaling

- Chips in the 1970's and 1980's were designed using $V_{DD} = 5$ V
- As technology improved, V_{DD} dropped
  - Avoid frying tiny transistors
  - Save power
- 3.3 V, 2.5 V, 1.8 V, 1.5 V, 1.2 V, 1.0 V, …
- Be careful connecting chips with different supply voltages

Logic Family Examples

Logic Family	V_{DD}	V_{IL}	V_{IH}	V_{OL}	V_{OH}
TTL	5 (4.75 - 5.25)	0.8	2.0	0.4	2.4
CMOS	5 (4.5 - 6)	1.35	3.15	0.33	3.84
LVTTL	3.3 (3 - 3.6)	0.8	2.0	0.4	2.4
LVCMOS	3.3 (3 - 3.6)	0.9	1.8	0.36	2.7