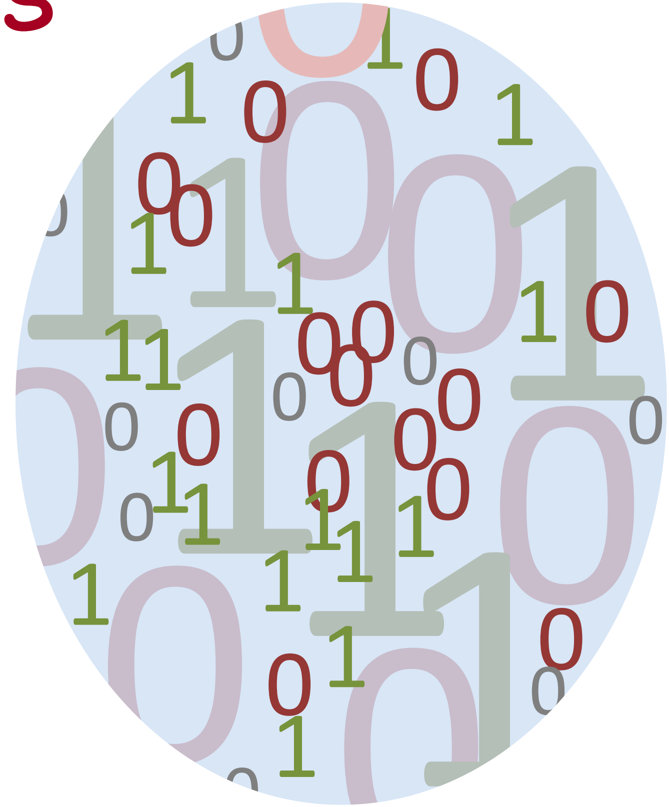
6.002x

CIRCUITS AND ELECTRONICS

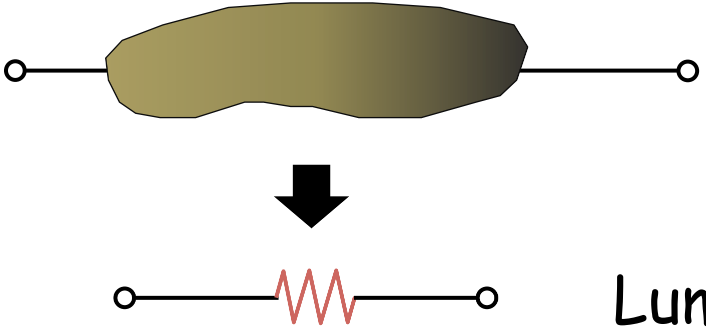
The Digital Abstraction



Reading: Chapter 5 of A&L

Review

- Discretize matter by observing lumped matter discipline



Lumped Circuit Abstraction

- Analysis tool kit

KVL/KCL, composition, node, superposition, Thévenin, Norton

In this Sequence

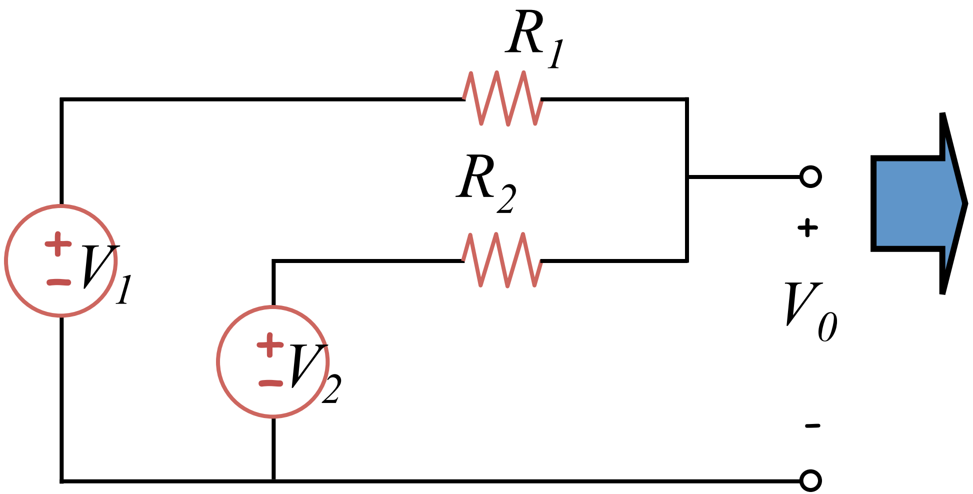
Discretize value ➡ Digital abstraction

Interestingly, we will see shortly that the tools learned in the previous three lectures are sufficient to analyze simple digital circuits

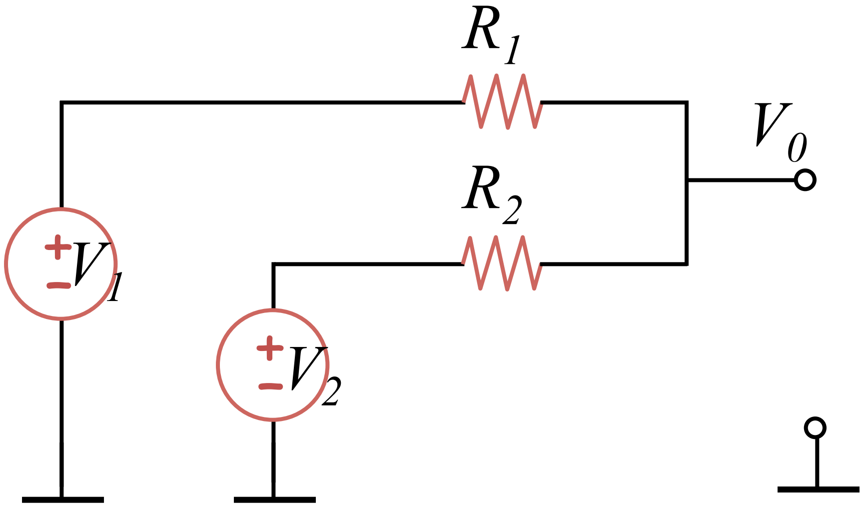
But first, why digital?

In the past …

Analog signal processing



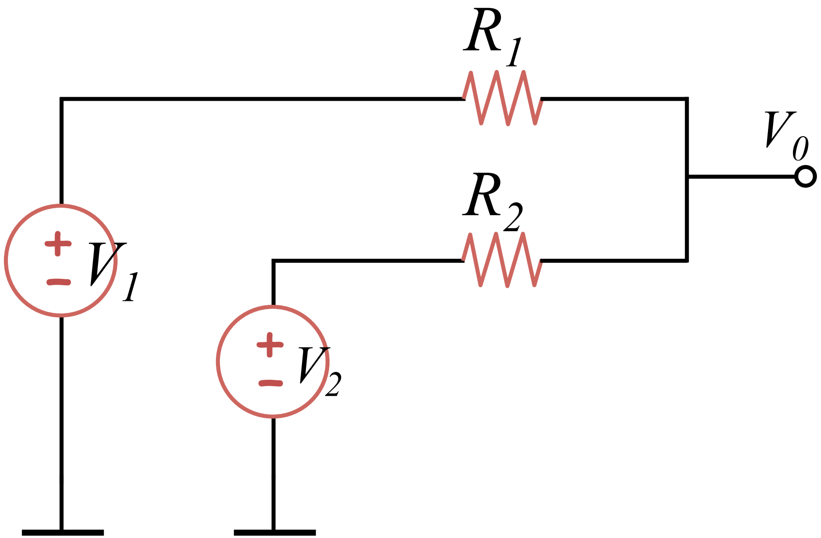
V_1 and V_2 might represent the outputs of two sensors, for e.g.



Shorthand notation (from node method)

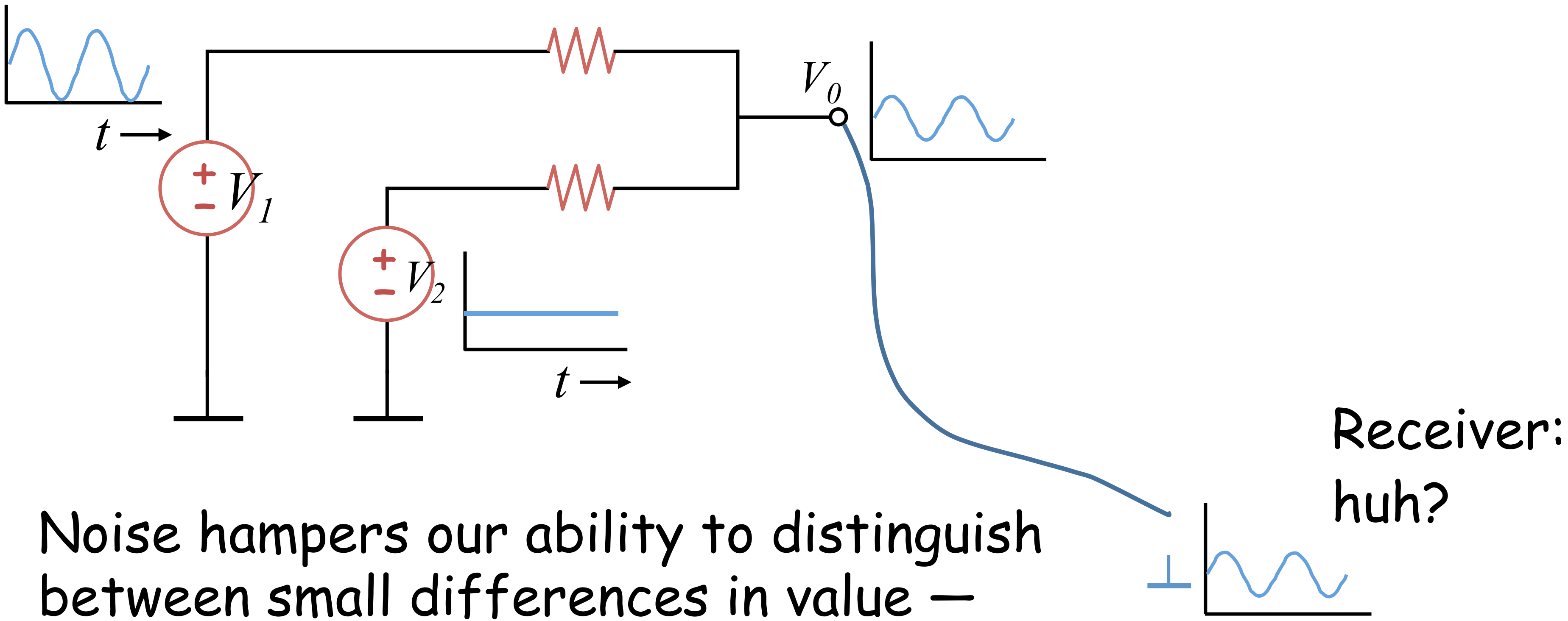
Why digital?

Analog signal processing



The above is an "adder" circuit.

Noise Problem with Analog



Noise hampers our ability to distinguish between small differences in value — e.g. between 3.1V and 3.2V.

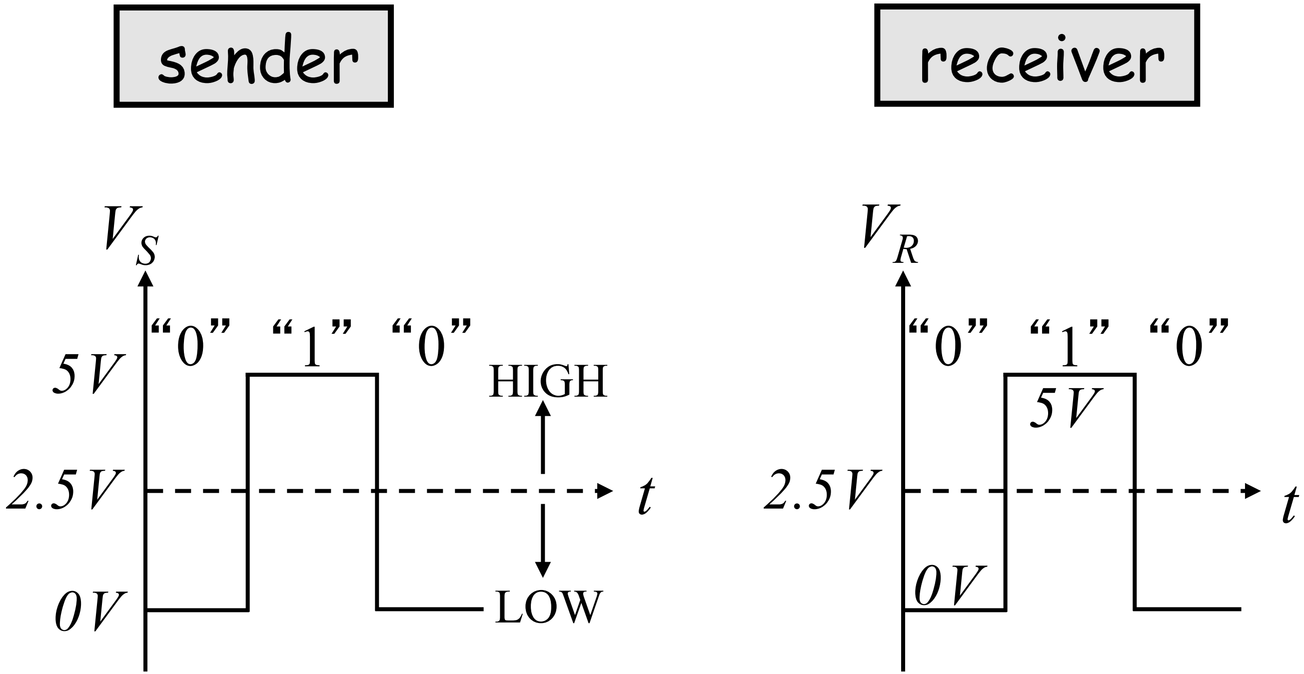
Idea: Value Discretization (or lumped values)

Restrict values to be one of two

...like two digits 0 and 1

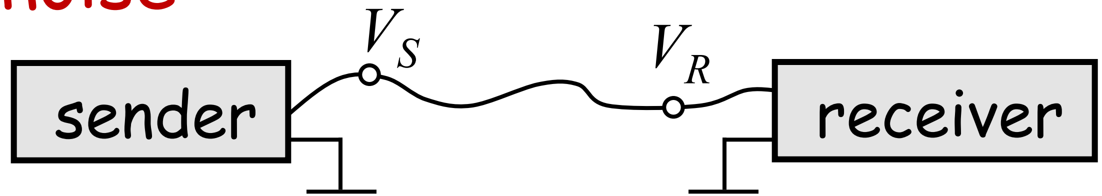
Why is this discretization useful?

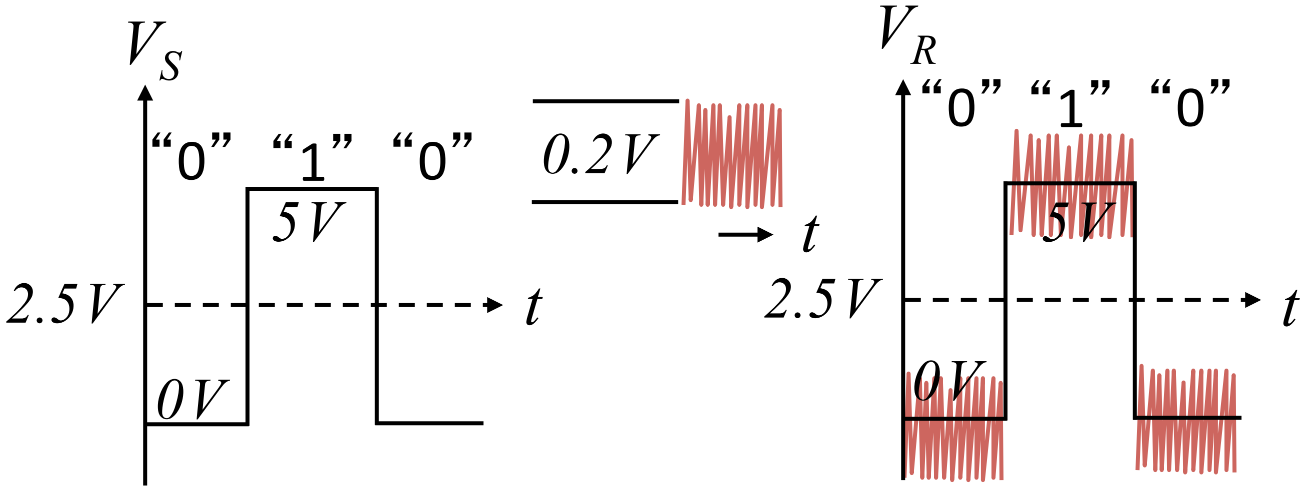
Digital System



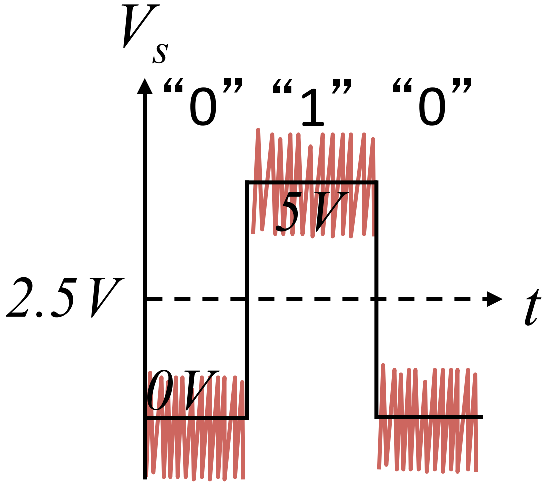
Digital System

With noise





Digital System

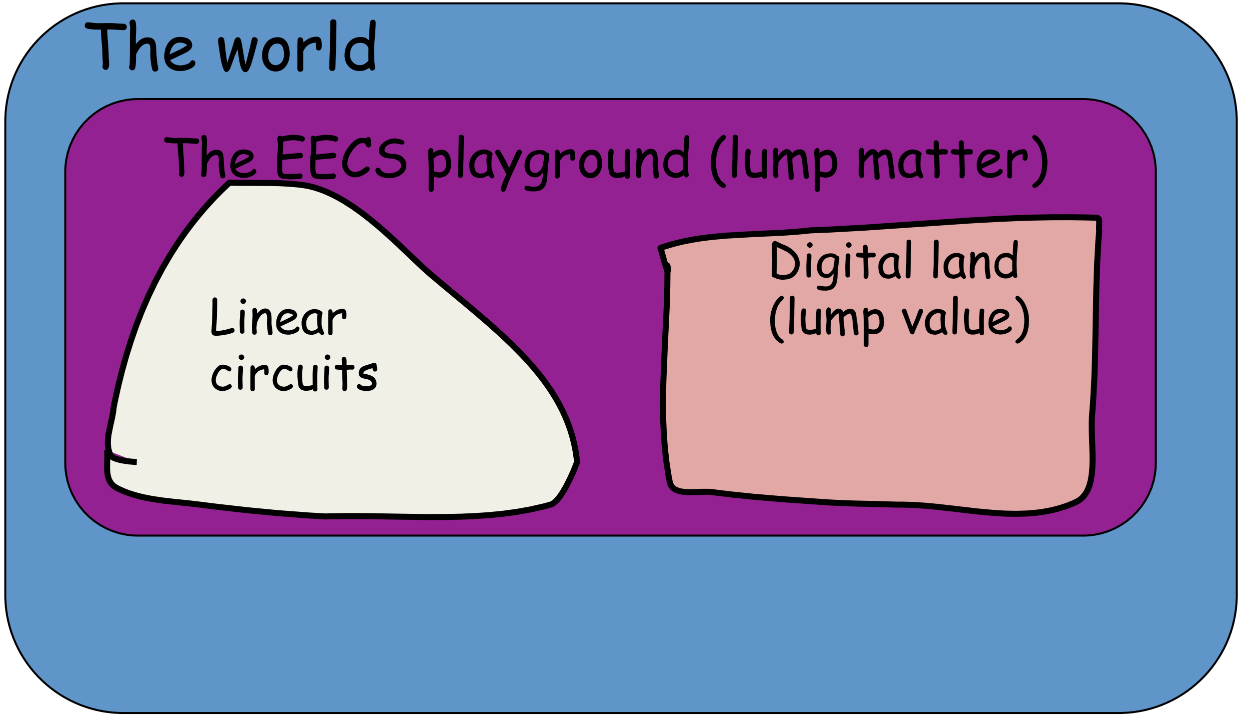


Better noise immunity → Lots of "noise margin"

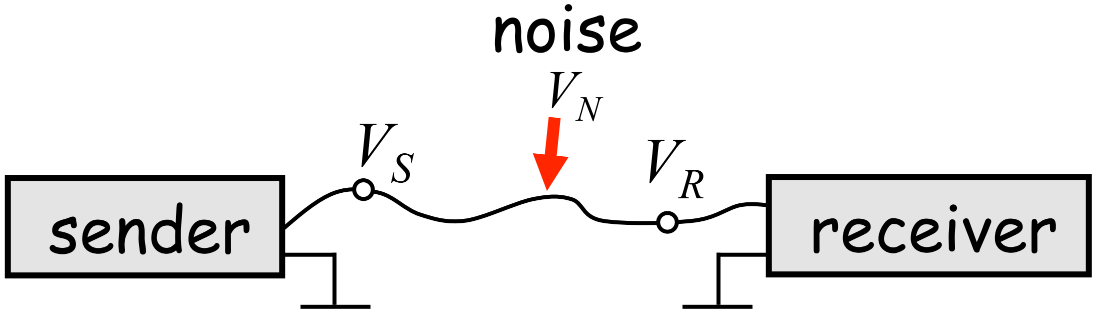
For "1": noise margin $5V$ *to* $2.5V = 2.5V$

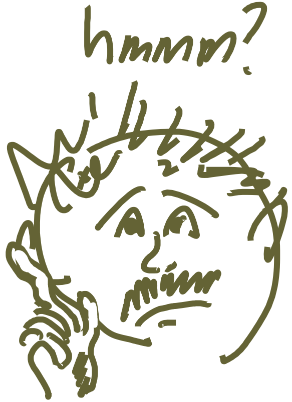
For "0": noise margin $0V$ *to* $2.5V = 2.5V$

The Big Picture

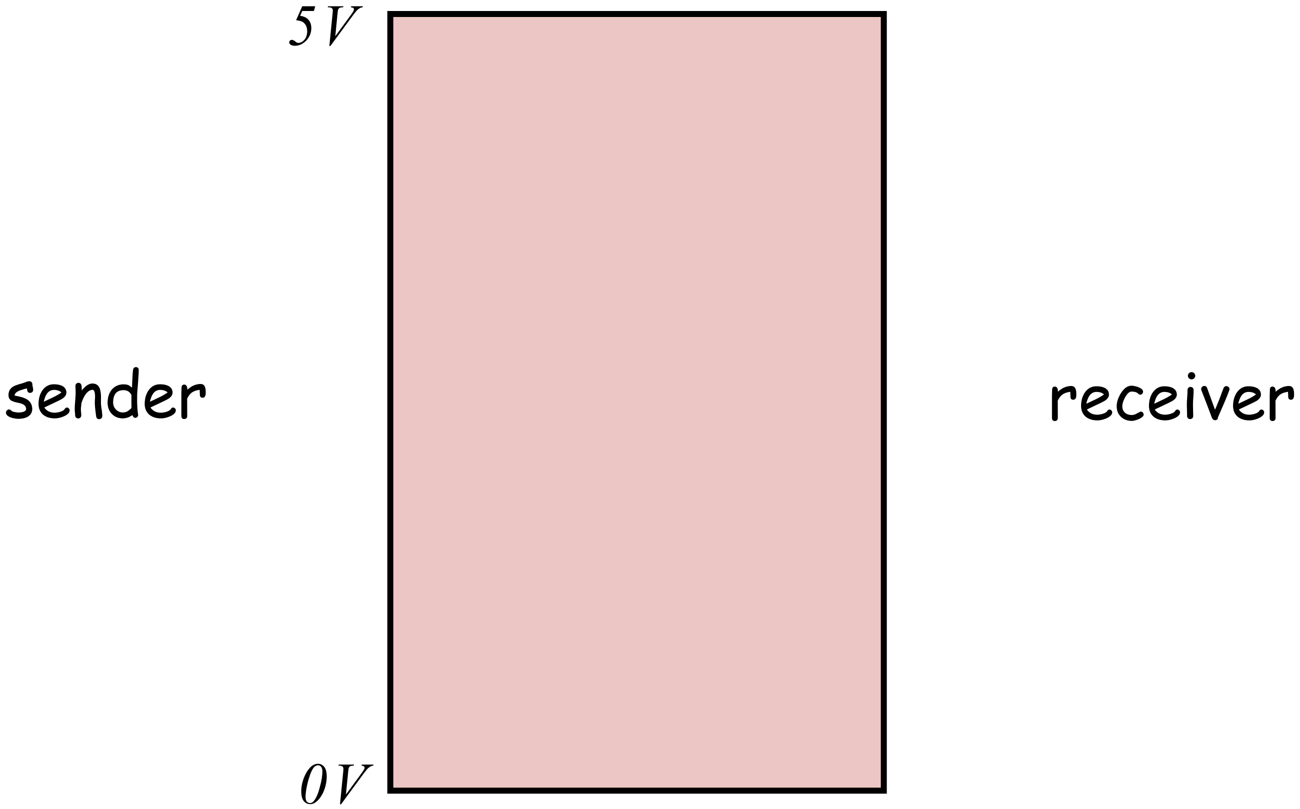


Digital System Sender-Receiver Contract





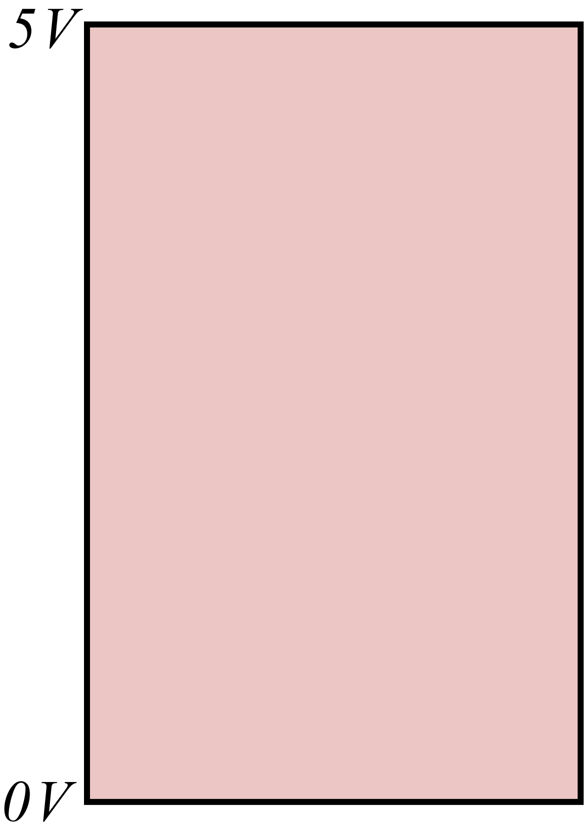
Voltage Thresholds and Logic Values



But, but, but … What about 2.5V?

Hmmm… Idea! Create "no man's land" or forbidden region

sender

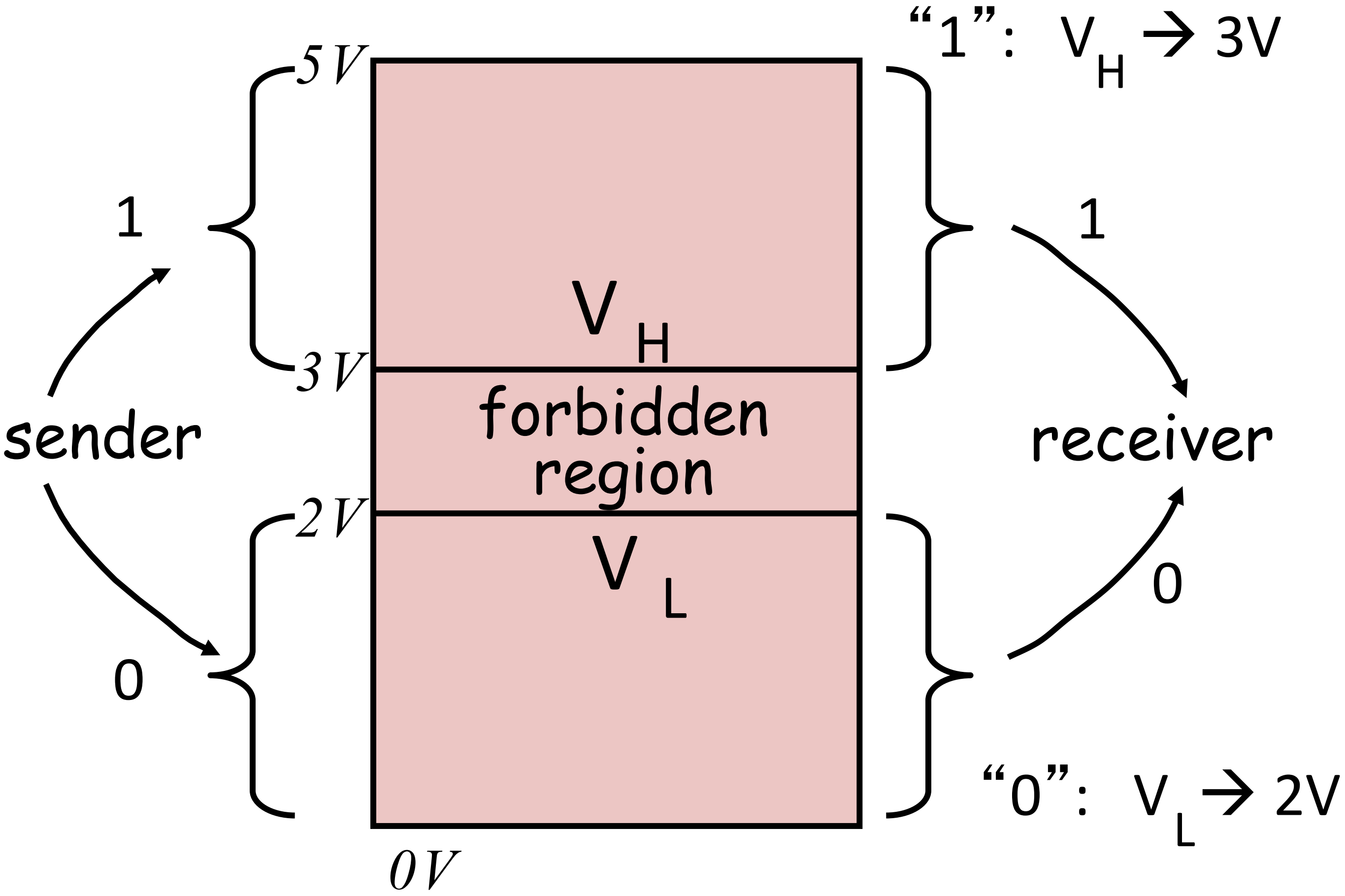


receiver

Remember, we can do so with impunity because it is our choice as to what discipline we agree on in our digital playground

Does this work?

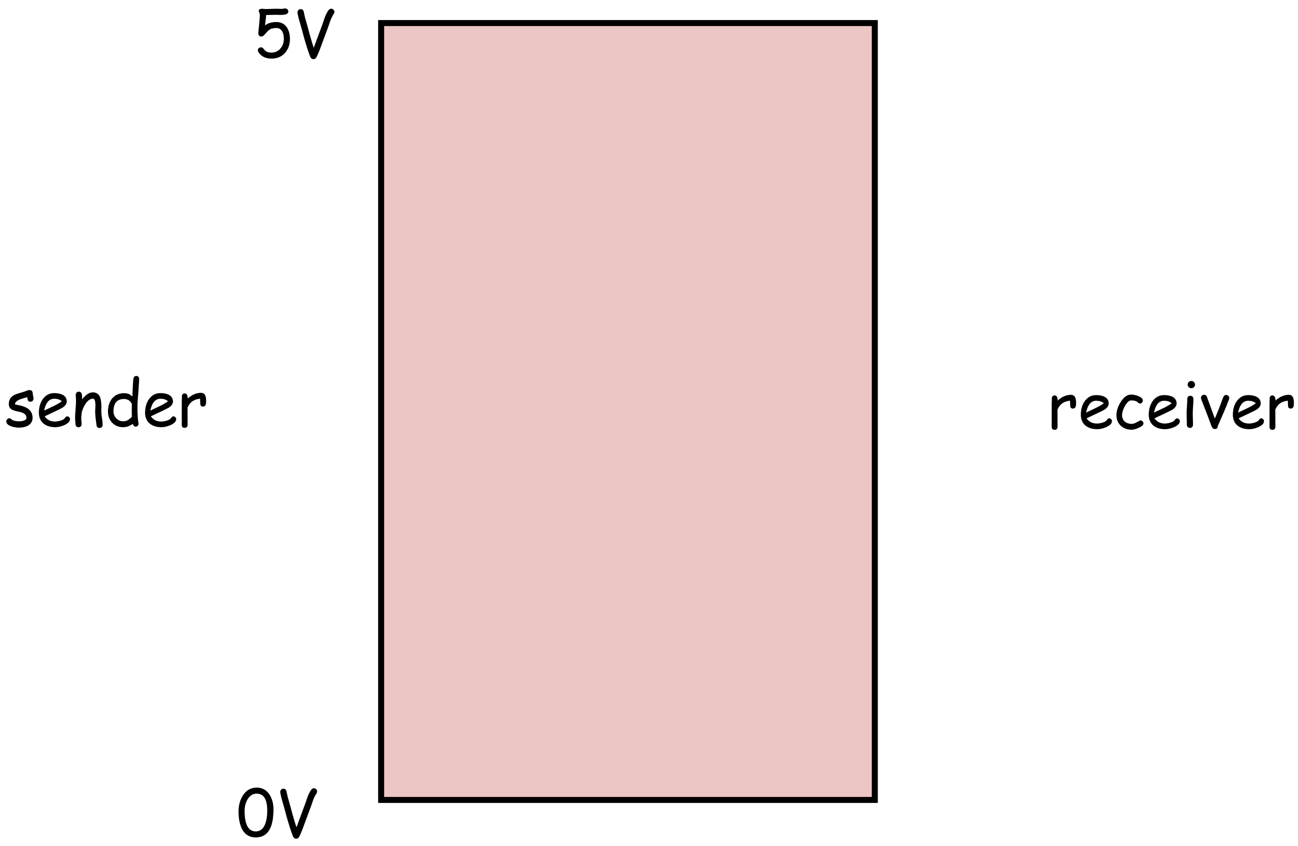
"No Man's Land" or Forbidden Region



Where's the noise margin?

What if the sender sent 1: V_H

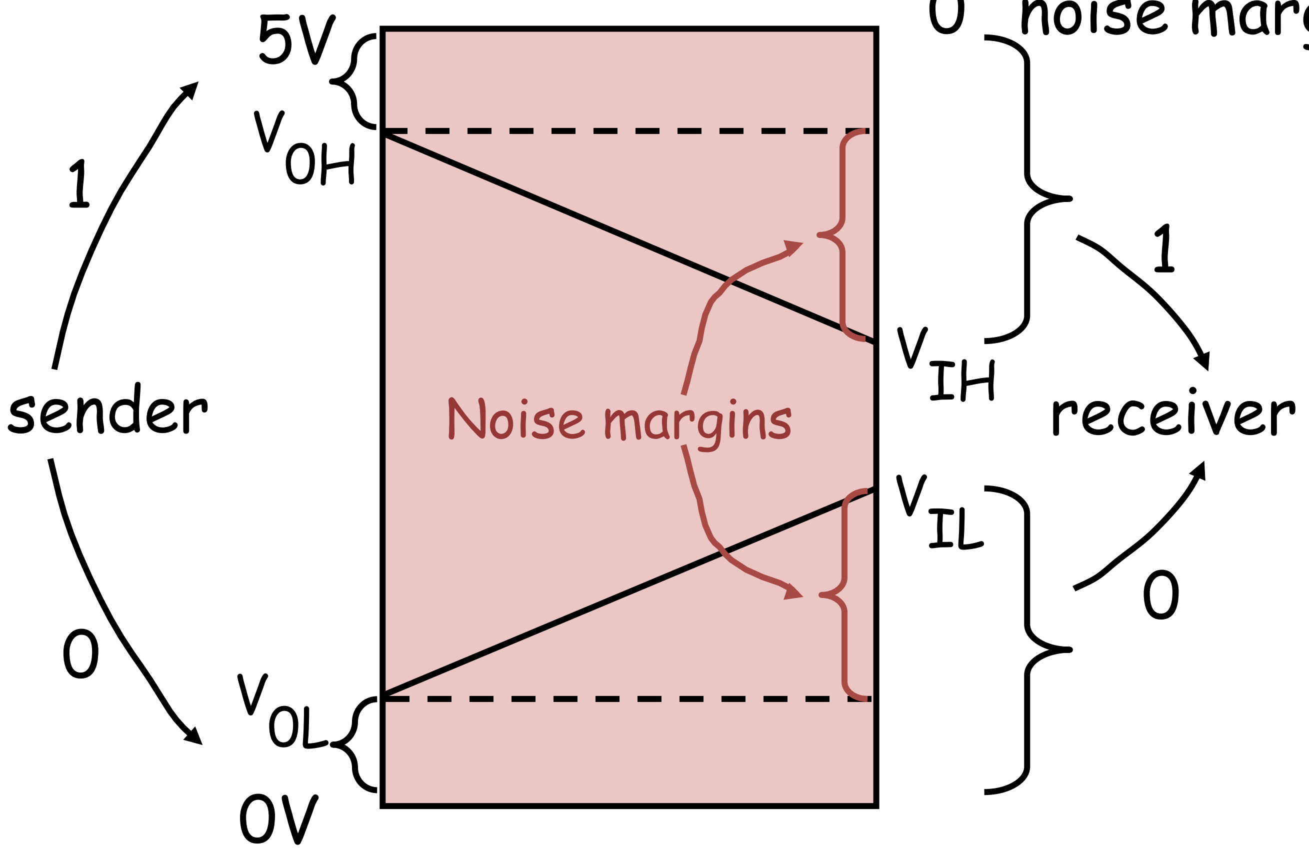
Hold the Sender to Tougher Standards!



Noise Margins

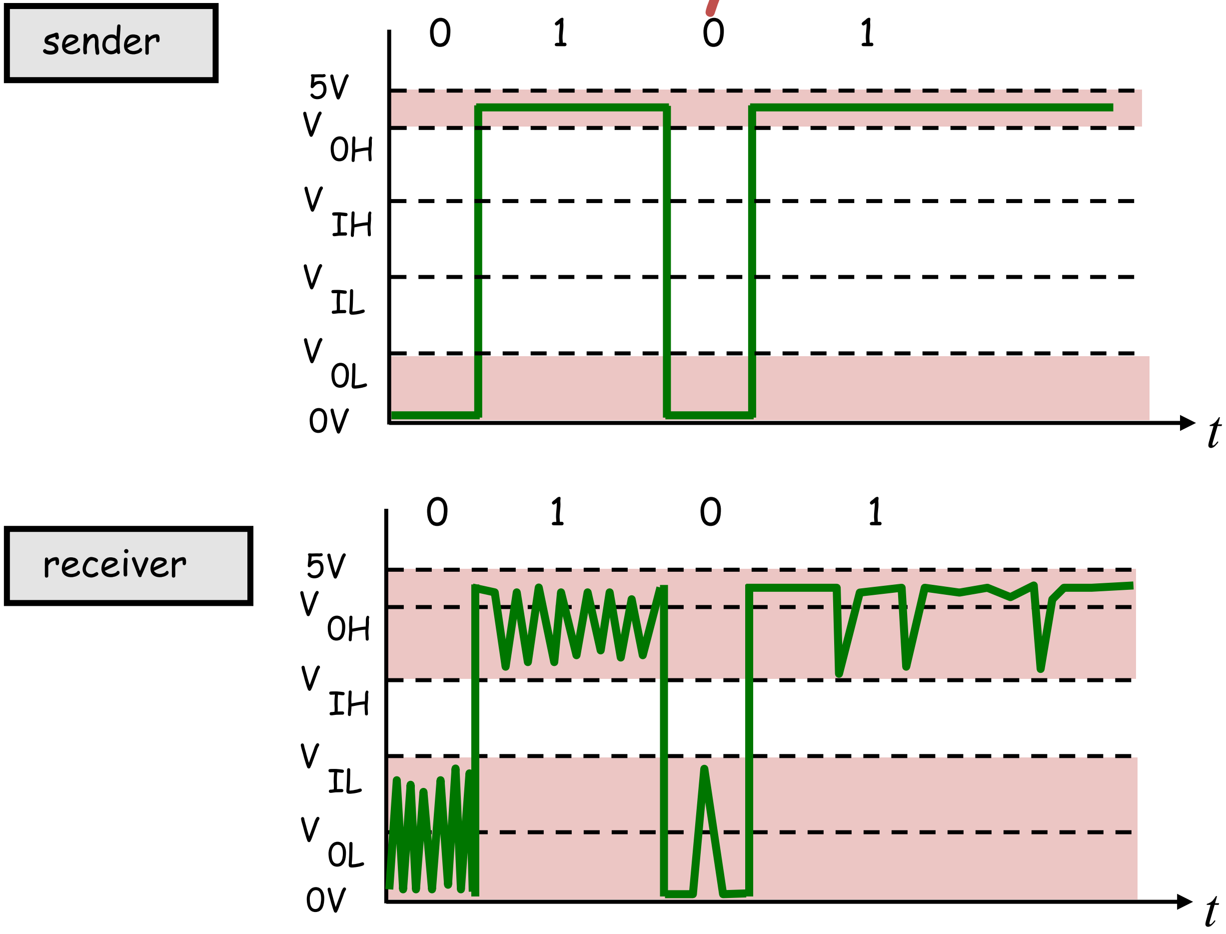
"1" noise margin:

"0" noise margin:



Together, the V_{OH}, V_{IH}, V_{OL}, V_{IL} thresholds define a discipline or standard that digital devices follow so they can talk to each other

Noise Immunity



Digital systems follow static discipline: if inputs to the digital system meet valid input thresholds, then the system guarantees its outputs will meet valid output thresholds.

Processing Digital Signals

Recall, we have only two values –

1,0 ⇨ Map naturally to logic: T, F

⇨ Can also represent numbers

What is 1011?

Check Chapter 5.6 of A&L

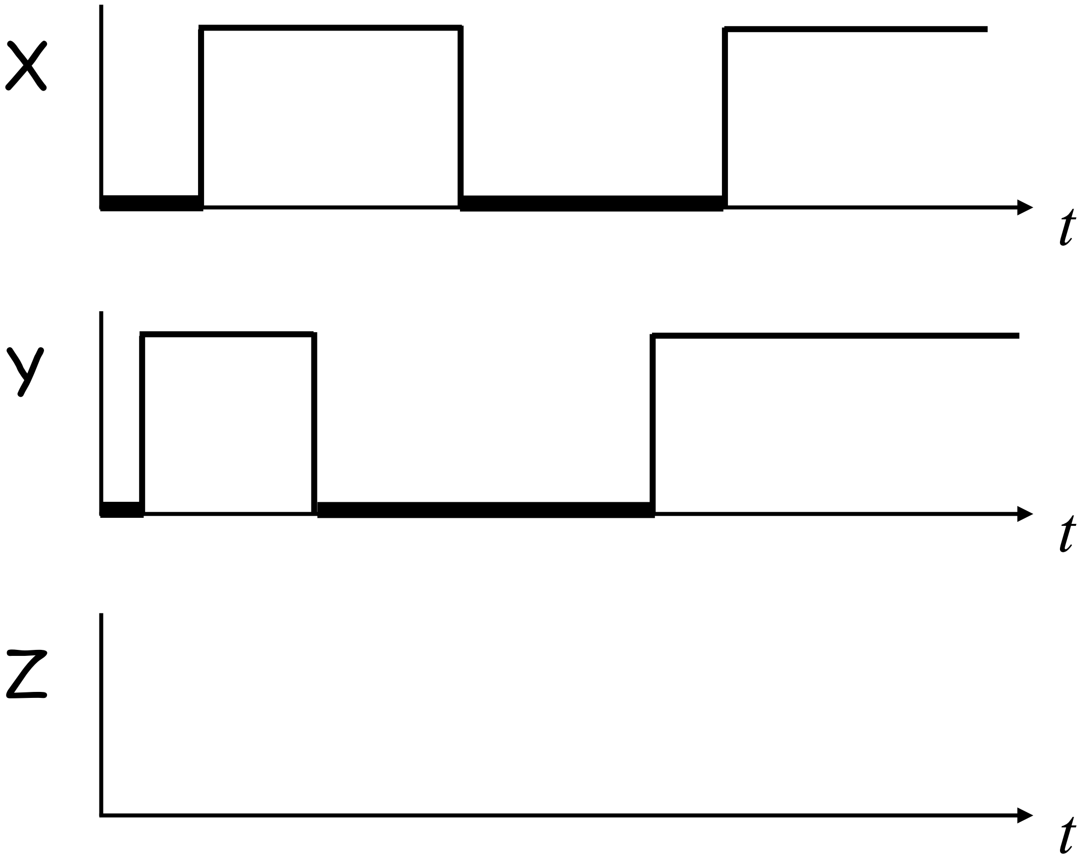
Processing Digital Signals

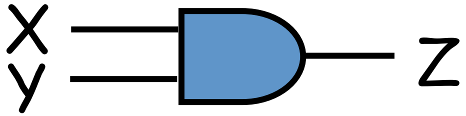
Boolean Logic

⇨ If **X** is true and **Y** is true
Then **Z** is true, else **Z** is false.

Processing Digital Signals

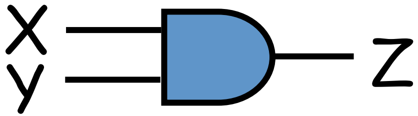
What is the Output Of This Gate?





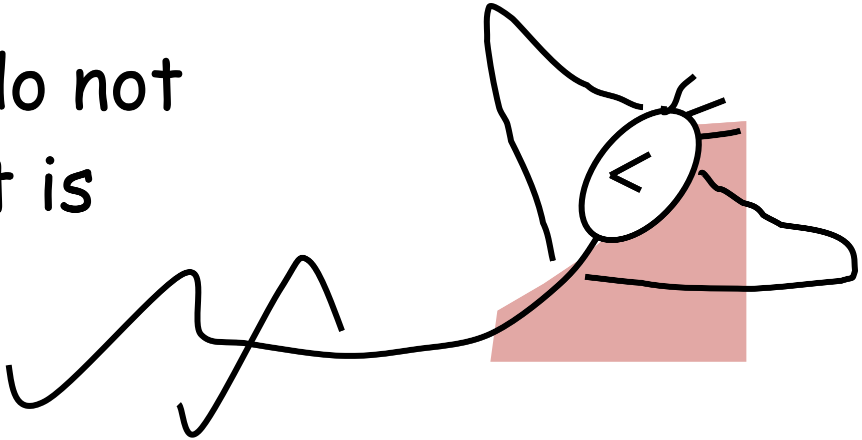
$Z = X \bullet Y$

Combinational Gate Abstraction

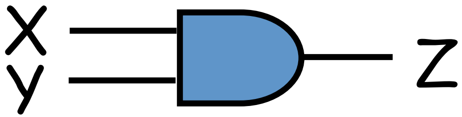


- Adheres to static discipline
- Outputs are a function of inputs alone.

Digital logic designers do not have to care about what is inside a gate.



Logic Gates



AND gate

x	y	z
0	0	0
0	1	0
1	0	0
1	1	1

Another Gate Example

If (**A** is true) OR (**B** is true)

then **C** is true

else **C** is false

Digital Circuits

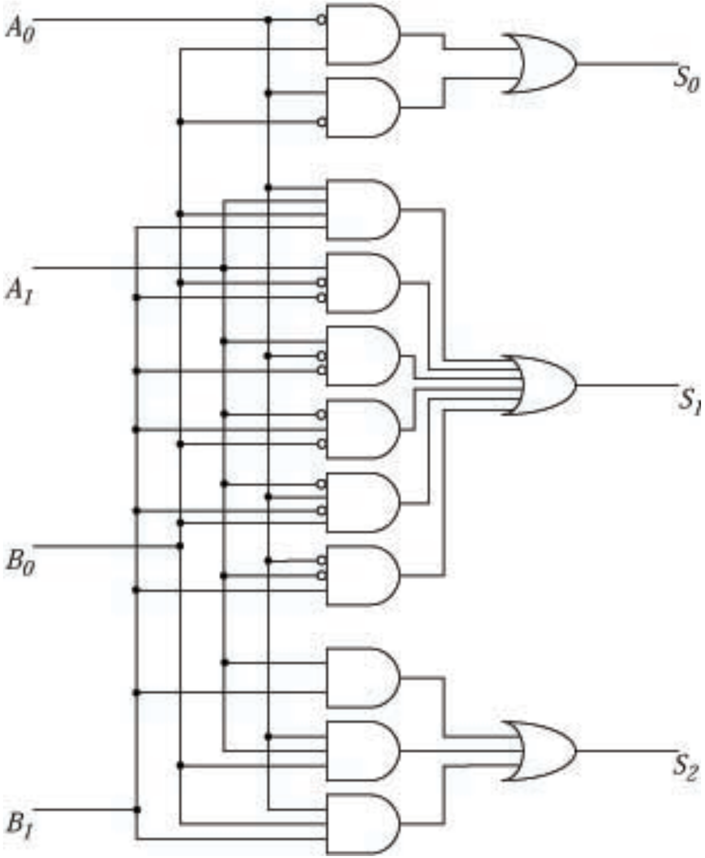
Implement: $output = A + \overline{B \cdot C}$

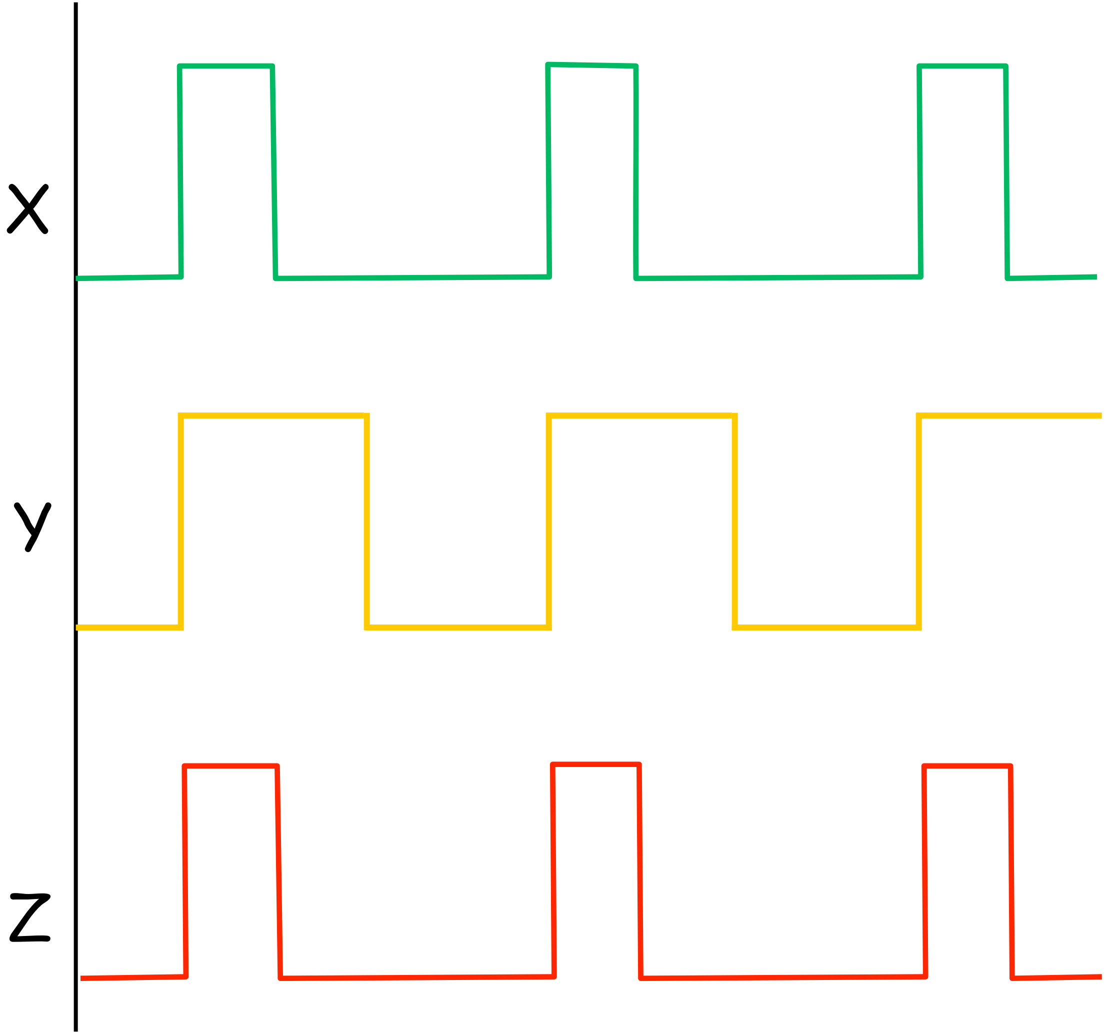
Representing Numbers

Numbers larger than 1 can be represented using multiple binary digits and coding, much like using multiple decimal digits to represent numbers greater than 9.

The binary number 101 has decimal value:

A Two-Bit Adder Circuit





Demo

$$z = x \cdot y$$