



adders, clocks

CS 2130: Computer Systems and Organization 1
January 30, 2026

Announcements

- Homework 1 due Monday

Our story so far

- Transistors
- Information modeled by voltage through wires (1 vs 0)

• Gates:



- Operate on 1-bit input producing 1-bit output
- Multi-bit values: representing integers
 - Signed and unsigned
 - **Bitwise operations** on them as bit vectors
- Floating point

$$\begin{array}{r} \downarrow \\ x = 101101 \\ y = 011011 \\ \hline z = \end{array}$$

Multi-bit Calculations

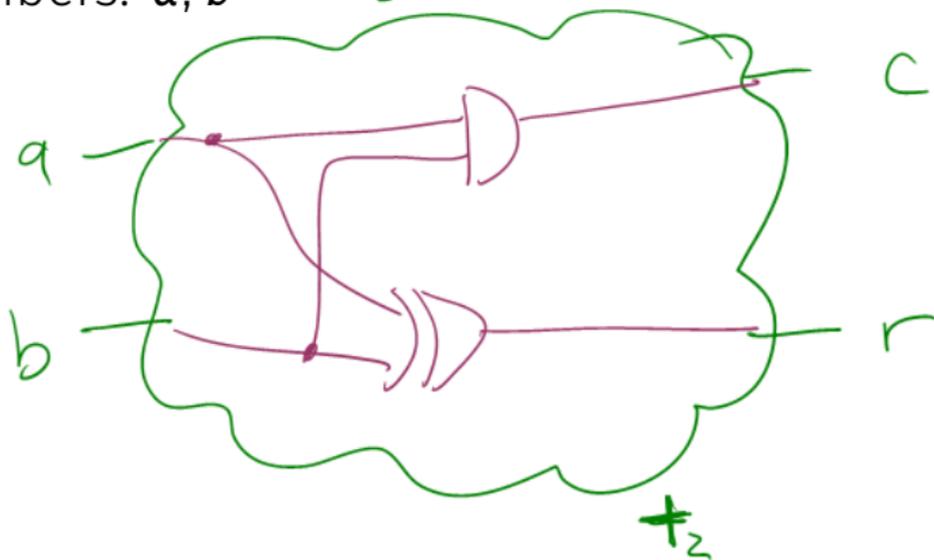
How to do the *work* of multi-bit?

Things like...

- Add integers to get integer answers

Adder

Add 2 1-bit numbers: $a, b \rightarrow 2 \text{ bits}$

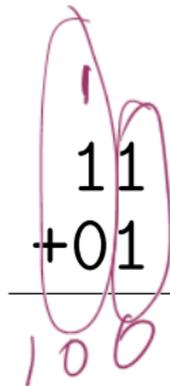


Adder

Can we use this in parallel to add multi-bit numbers?

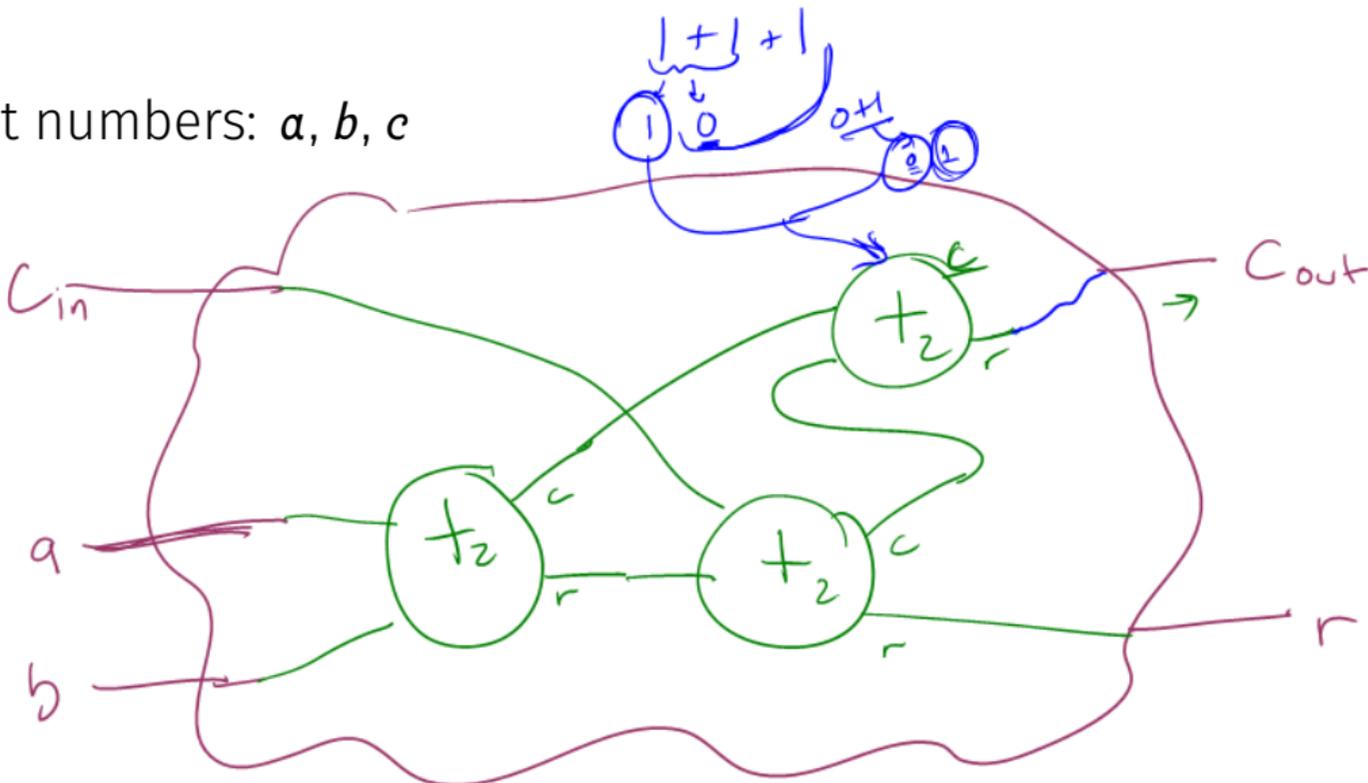
Adder

Can we use this in parallel to add multi-bit numbers? What is missing? Consider:

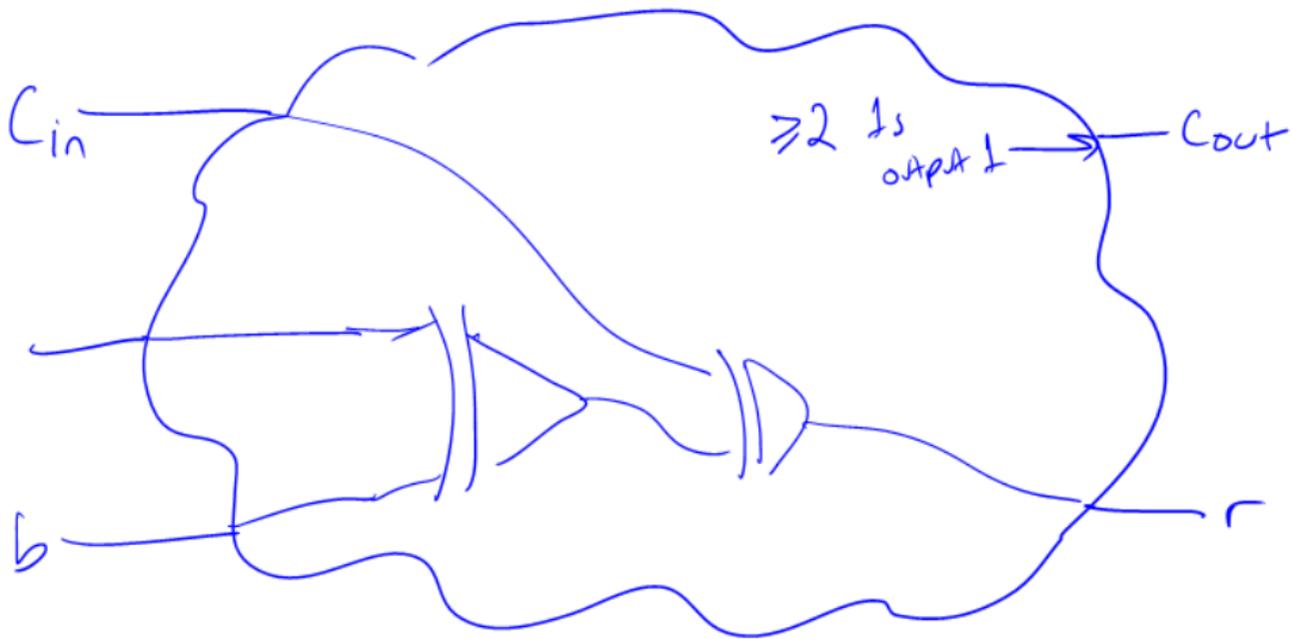
$$\begin{array}{r} 11 \\ +01 \\ \hline 100 \end{array}$$
A handwritten diagram illustrating a 2-bit adder. It shows the addition of 11 and 01. The result is 100. A vertical oval encircles the carry bit '1' and the first '1' of the second number. A horizontal oval encircles the two '1's in the second column. A horizontal line is drawn under the second column, and the result '100' is written below it.

3-input Adder

Add 3 1-bit numbers: a , b , c



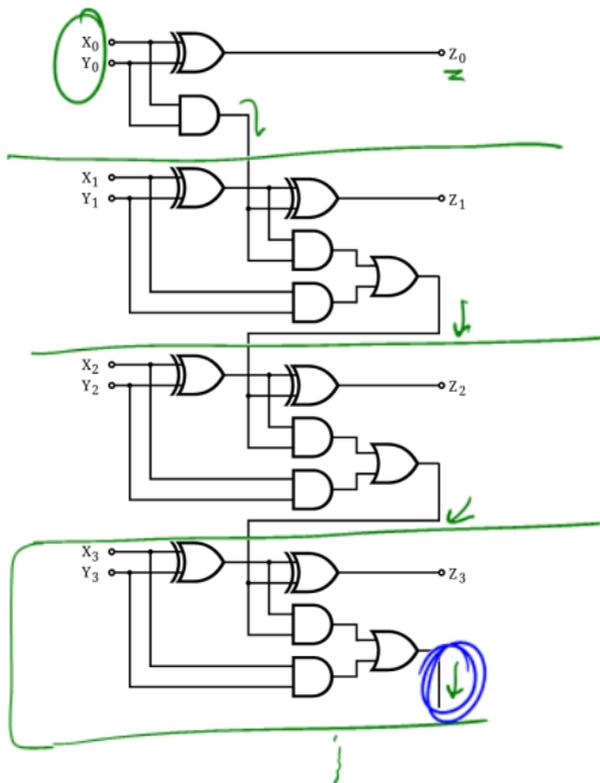
abc _i	c _r
000	00
001	01
010	01
011	10
100	01
101	10
110	10
111	11



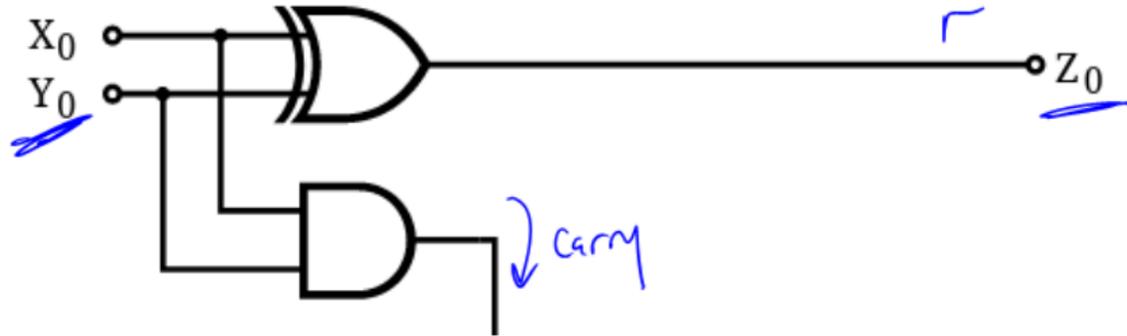
Ripple-Carry Adder

$$\begin{array}{r} x_3 x_2 x_1 x_0 \\ + y_3 y_2 y_1 y_0 \\ \hline z_3 z_2 z_1 z_0 \end{array}$$

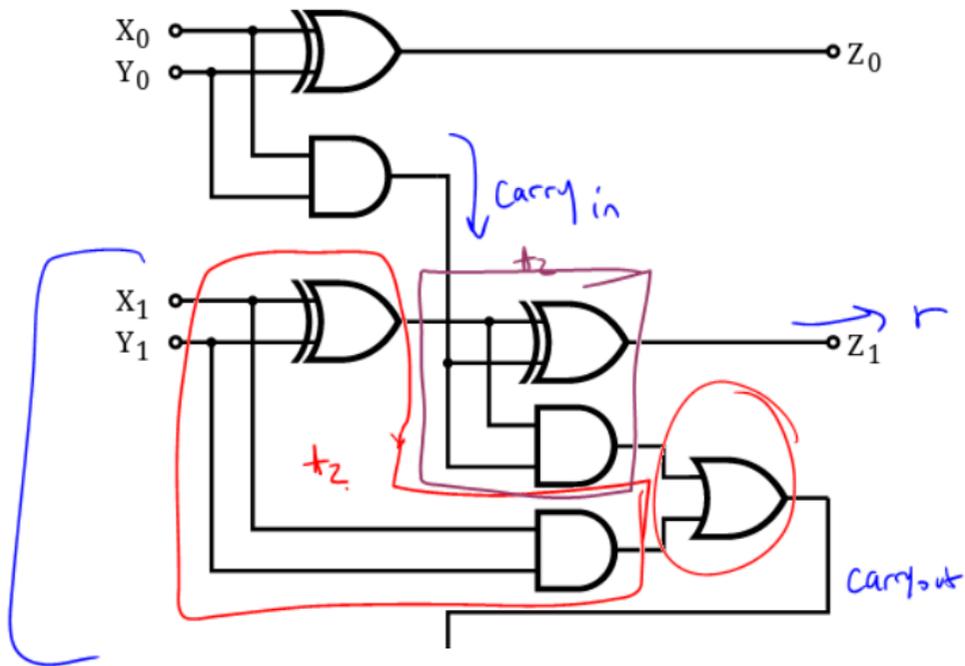
$$\begin{array}{r} 11 \\ 1111 \\ + 1110 \\ \hline 1101 = -3_{10} \end{array}$$



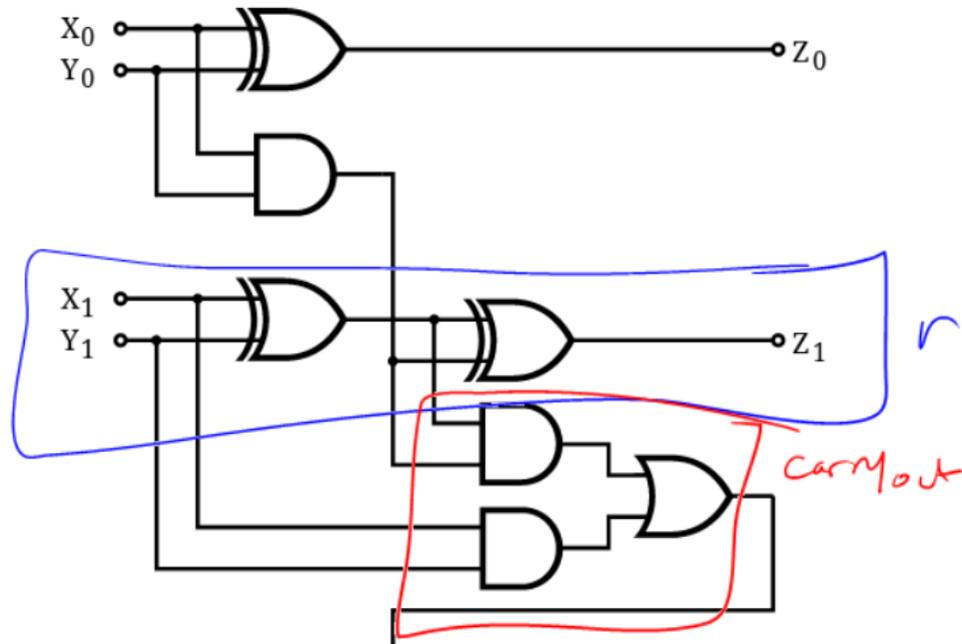
Ripple-Carry Adder: Lowest-order Bit



Ripple-Carry Adder: In General



Ripple-Carry Adder: In General

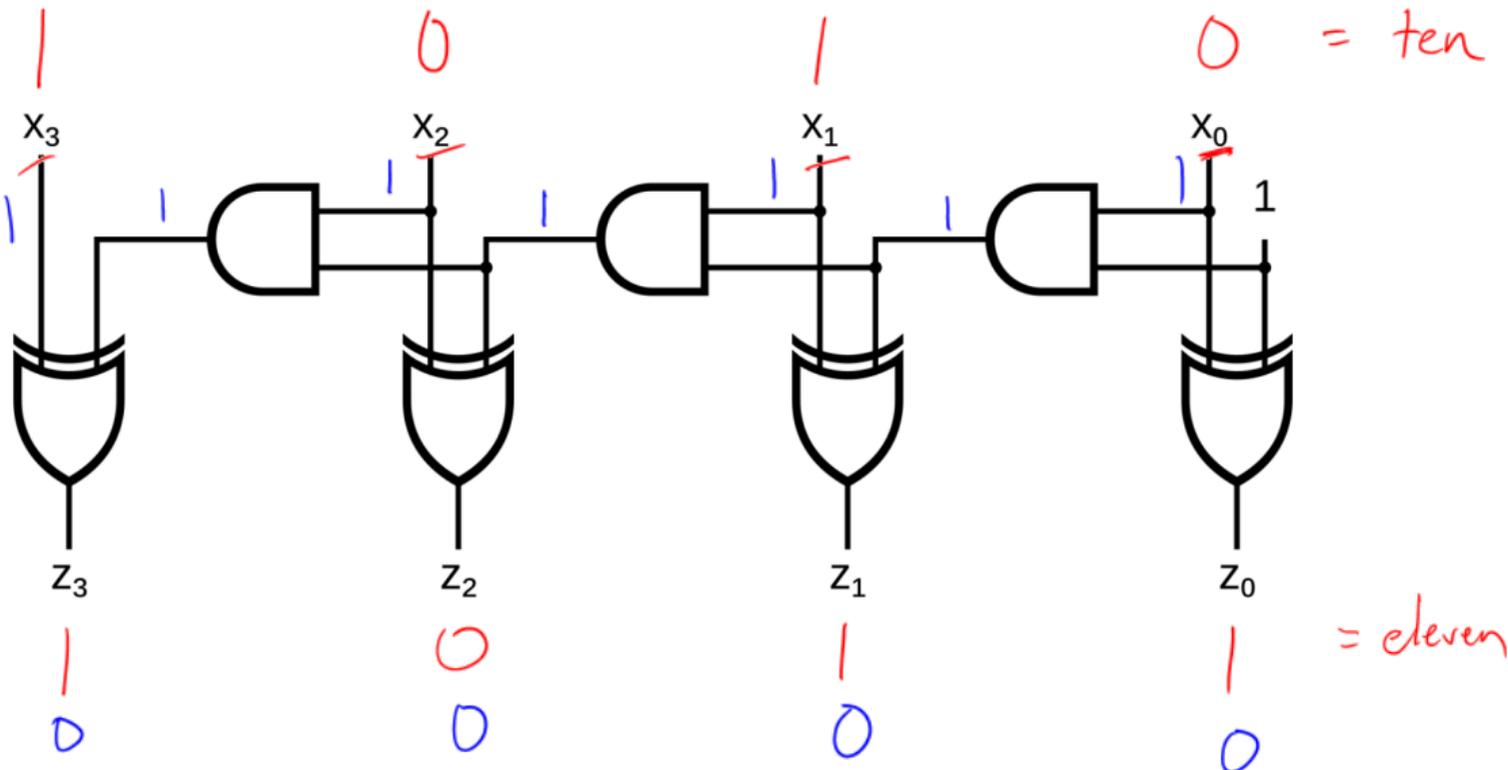


What does this circuit do?

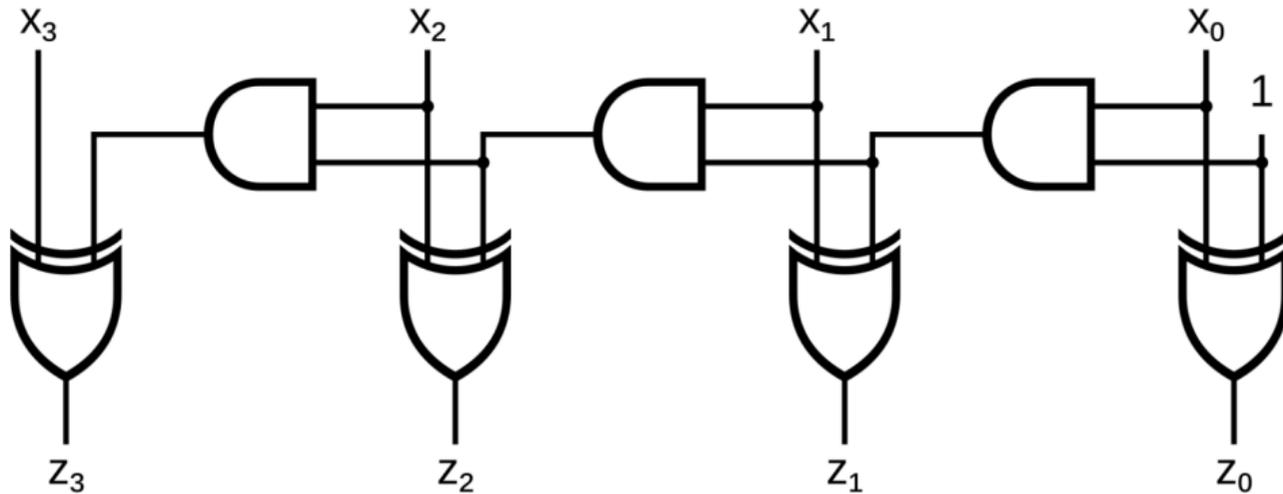
$$\begin{array}{r} 1010 = -6 \\ + 0101 \\ \hline 0110 = 6 \end{array}$$

$$\begin{array}{r} 1011 = -5 \\ + 0100 \\ \hline 0101 = 5 \end{array}$$

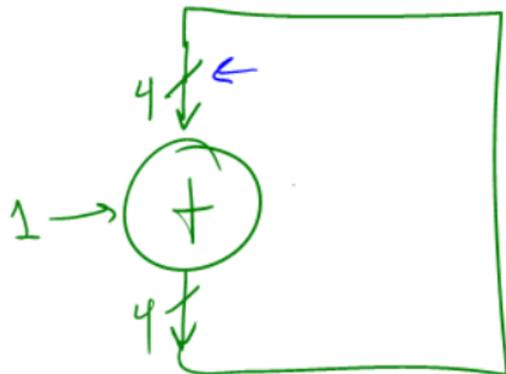
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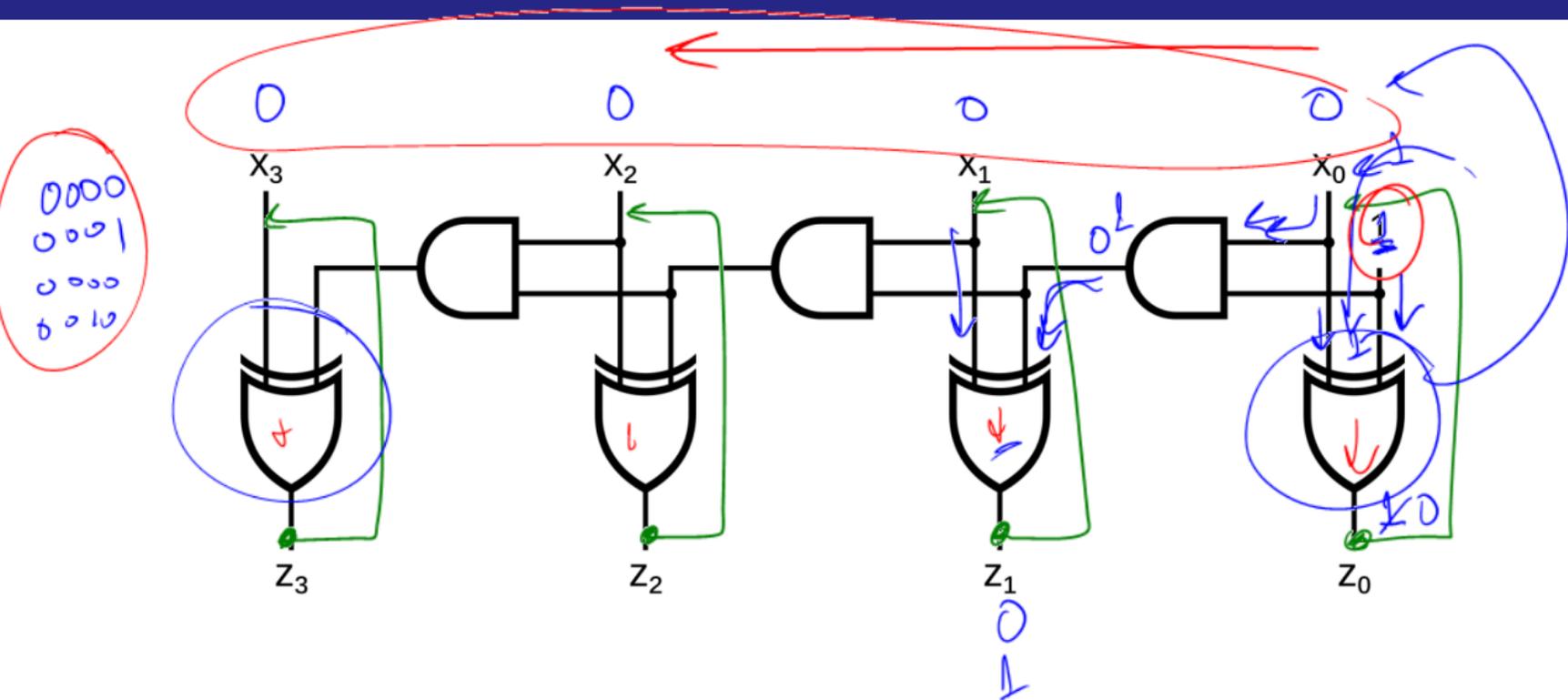
Increment Circuit



Building a Counter

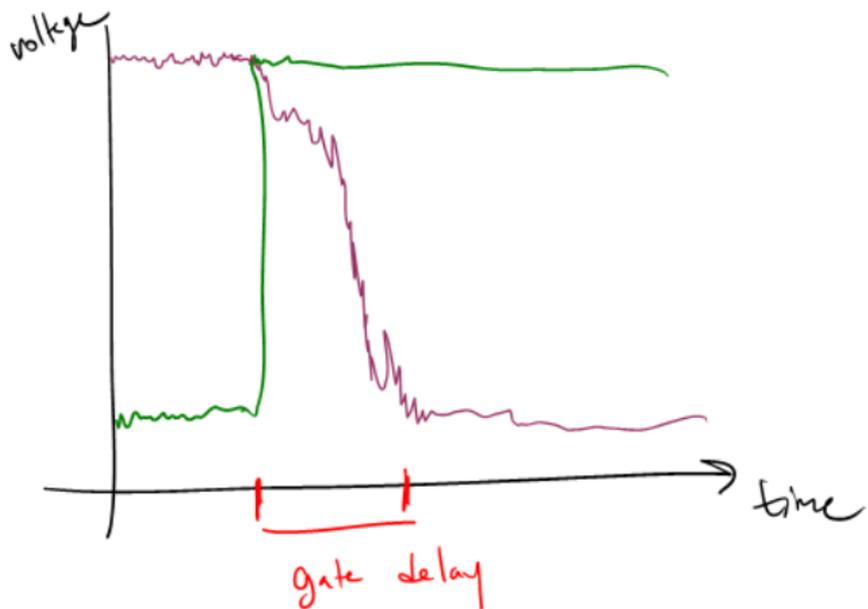
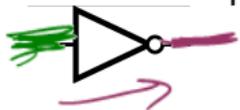


Building a Counter



Gate Delay

What happens when I change my input?



Building a Counter - Waiting

