University of Virginia

Floating Point Numbers (From the last class)

CS 2130: Computer Systems and Organization 1

Xinyao Yi Ph.D.
Assistant Professor

University of Virginia | ENGINEERING

Floating Point Example

$$101.011_2$$

Floating Point Example

What does the following encode?

1	001110	1010101

What about 0?

Floating Point Numbers

Four cases:

- **Normalized**: What we have seen today

$$s\ eeee\ ffff = \pm 1.ffff \times 2^{eeee-\text{bias}}$$

- **Denormalized**: Exponent bits all 0

$$s\ eeee\ ffff = \pm 0.ffff \times 2^{1-\text{bias}}$$

- **Infinity**: Exponent bits all 1, fraction bits all 0 (i.e., $\pm\infty$)
- **Not a Number (NaN)**: Exponent bits all 1, fraction bits not all 0

More bits, circuits, adders

CS 2130: Computer Systems and Organization 1

Xinyao Yi Ph.D.
Assistant Professor

Announcements

- Homework 1 due September 15

Warm up!

Can I make an n-input AND from 2-input AND gates?

What about XOR gates?

Operations

So far, we have discussed:

- Addition: $x + y$
  - Can get multiplication
- Subtraction: $x - y$
  - Can get division, but more difficult
- Unary minus (negative): $-x$
  - Flip the bits and add 1

Operations (on Integers)

Bit vector: fixed-length sequence of bits (ex: bits in an integer)

- Manipulated by bitwise operations

Bitwise operations: operate over the bits in a bit vector

- Bitwise not: ~x - flips all bits (unary)
- Bitwise and: x & y - set bit to 1 if x, y have 1 in same bit
- Bitwise or: x | y - set bit to 1 if either x or y have 1
- Bitwise xor: x ^ y - set bit to 1 if x, y bit differs

Operations (on Integers)

Logical not: $!x$

- $!0 = 1$ and $!x = 0, \forall x \neq 0$
- Useful in C, no booleans
- Some languages name this one differently

Operations (on Integers)

Left shift: $x << y$ - move bits to the left

- Effectively multiply by powers of 2

Right shift: $x >> y$ - move bits to the right

- Effectively divide by powers of 2
- Signed (extend sign bit) vs unsigned (extend 0)

Floating Point Numbers

Four cases:

- **Normalized**: What we have seen today

$$s\ eeee\ ffff = \pm 1.ffff \times 2^{eeee-\text{bias}}$$

- **Denormalized**: Exponent bits all 0

$$s\ eeee\ ffff = \pm 0.ffff \times 2^{1-\text{bias}}$$

- **Infinity**: Exponent bits all 1, fraction bits all 0 (i.e., $\pm\infty$)
- **Not a Number (NaN)**: Exponent bits all 1, fraction bits not all 0

Our Story So Far

- Transistors
- Information modeled by voltage through wires (1 vs 0)
- Gates: & | ~ ^
- Multi-bit values: representing integers
  - Signed and unsigned
  - Bitwise operators on bit vectors
- Floating point

How to do the work of multi-bit?

Multi-bit Mux

Our first multi-bit example: mux

Adder

Add 2 1-bit numbers: a, b

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?

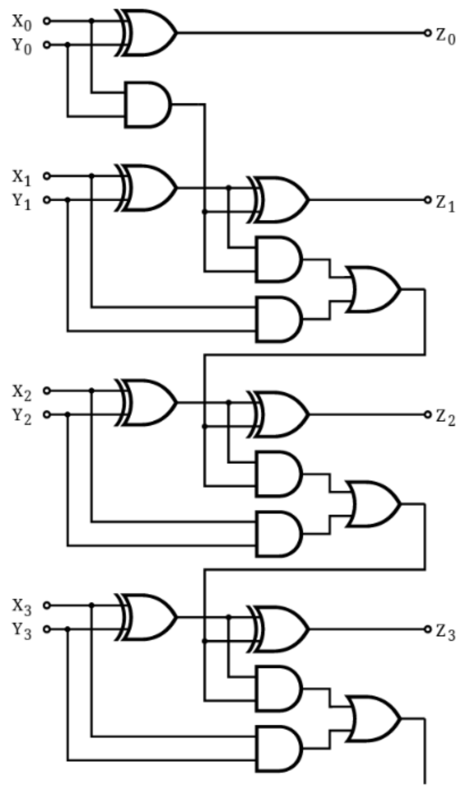
Consider:

```
  11
+01
----
```

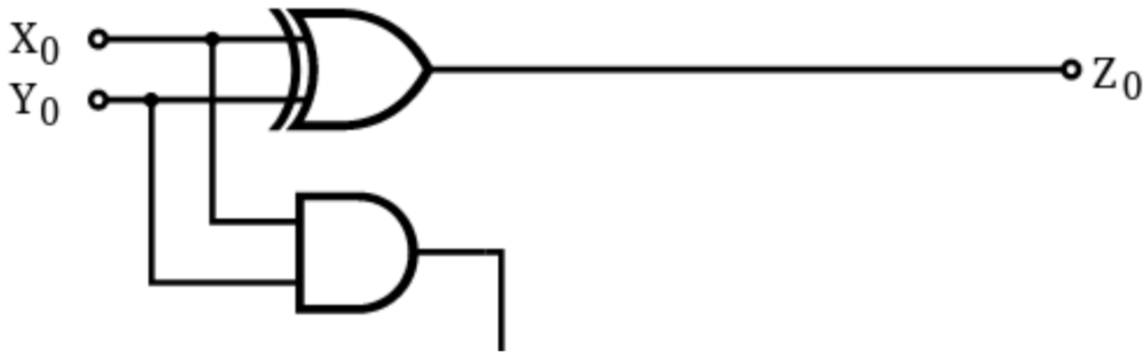
3-input Adder

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

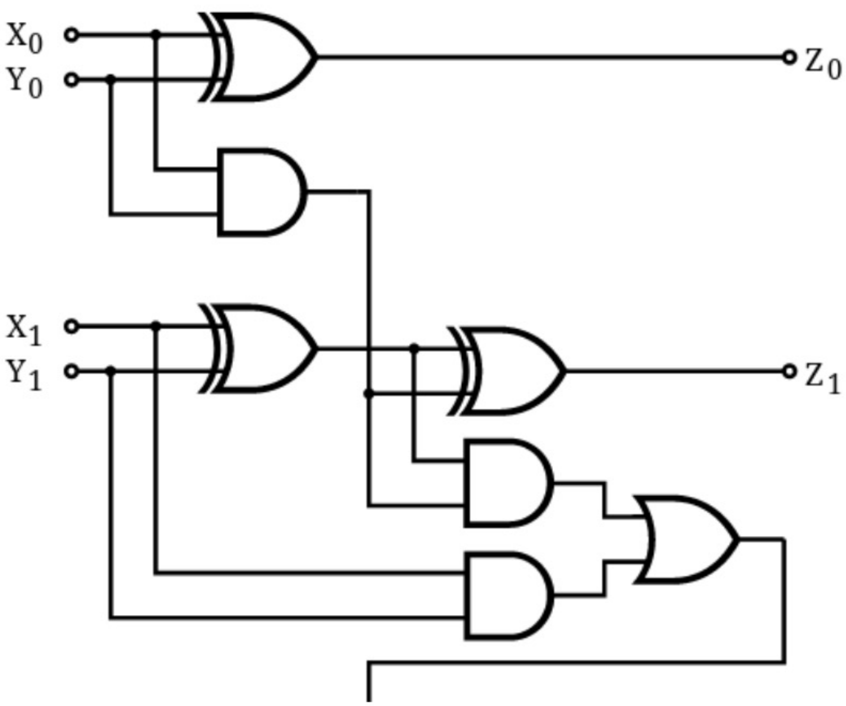
Ripple-Carry Adder



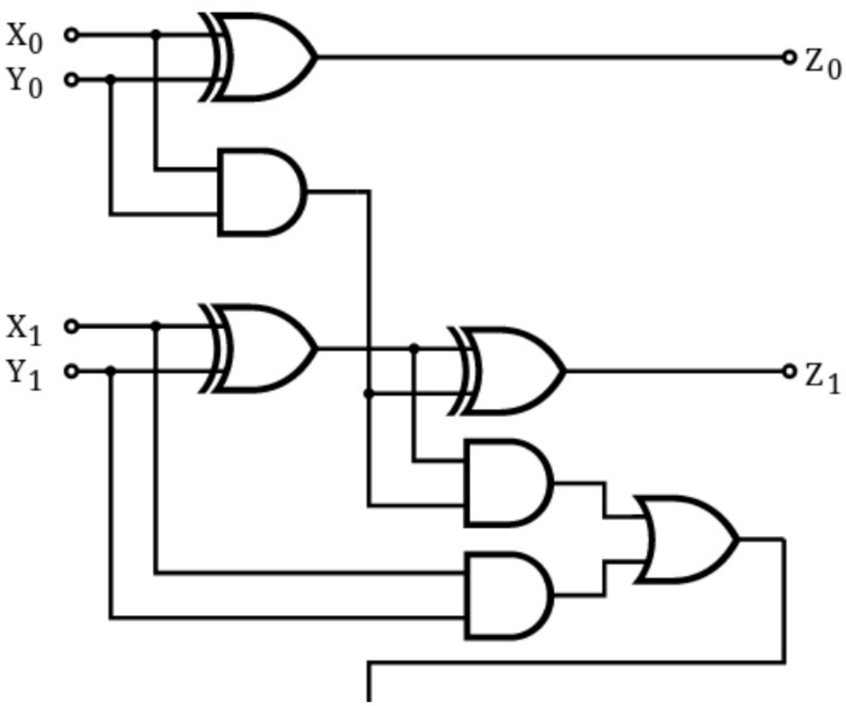
Ripple-Carry Adder: Lowest-order Bit



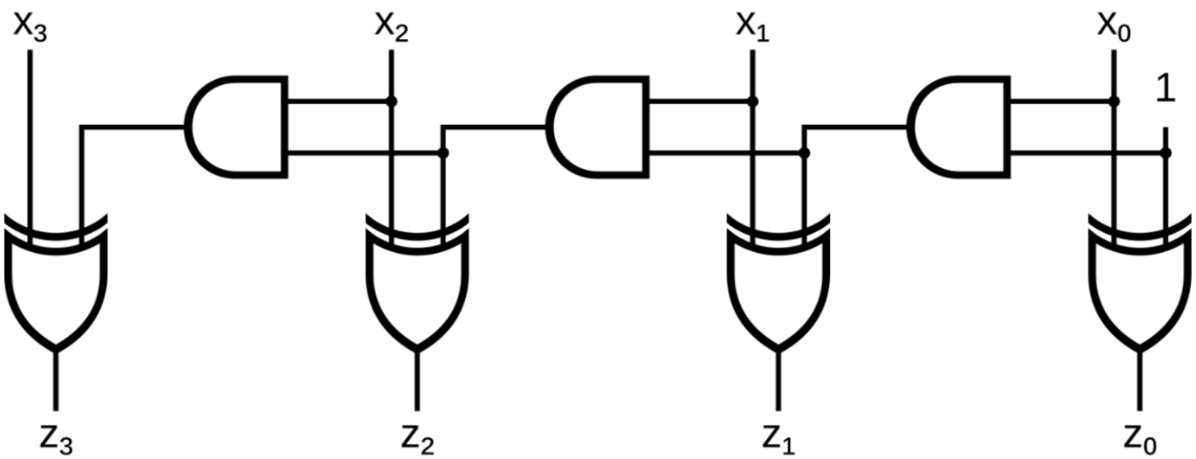
Ripple-Carry Adder: In General



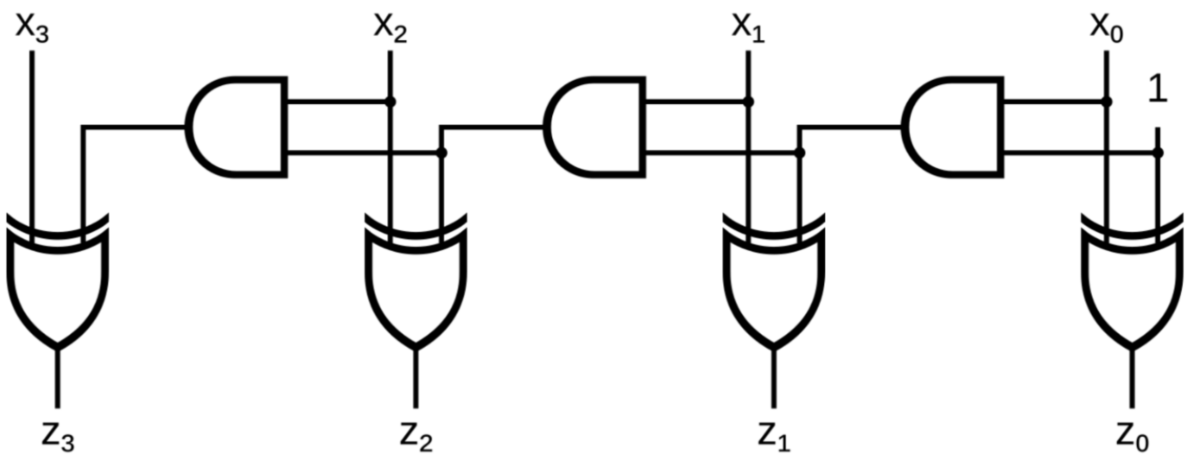
Ripple-Carry Adder: In General



What does this circuit do?

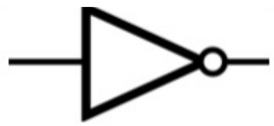


Increment Circuit



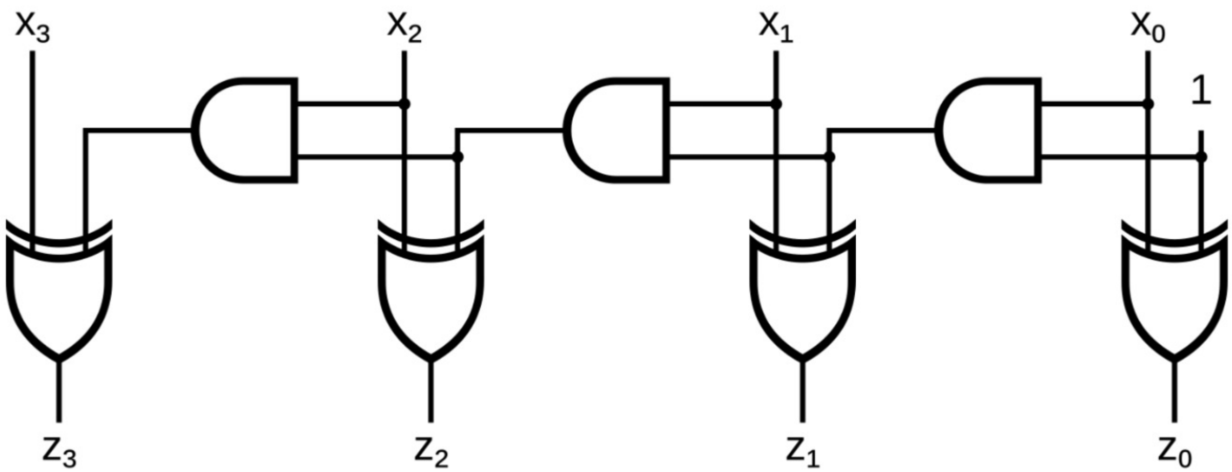
Gate Delay

What happens when I change my input?



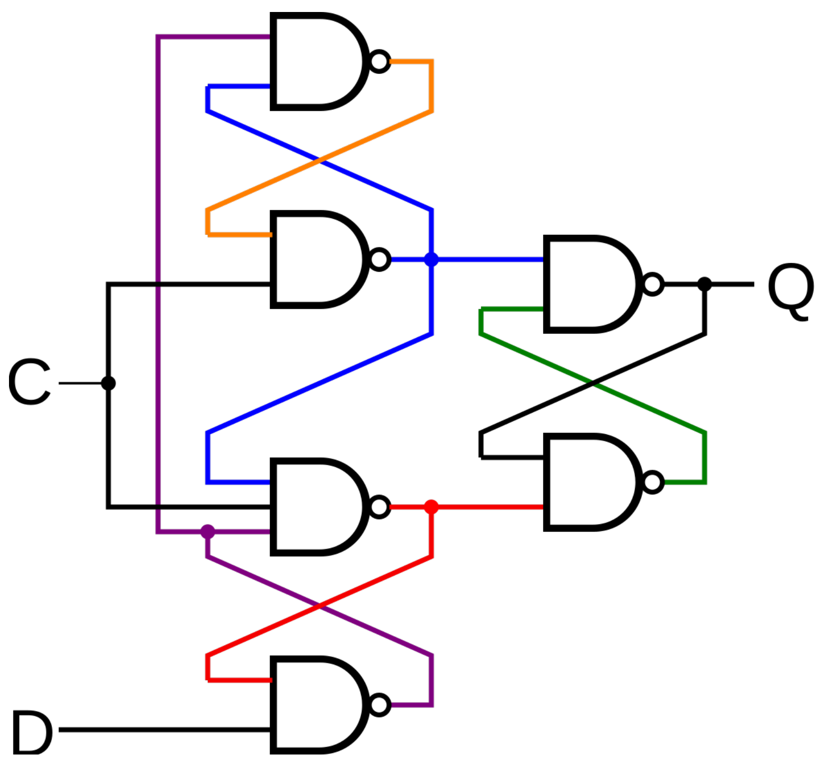
Building a Counter

Building a Counter

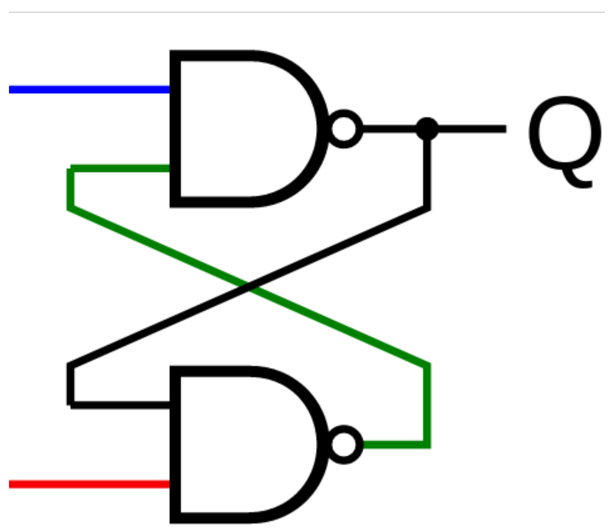


Building a Counter - Waiting

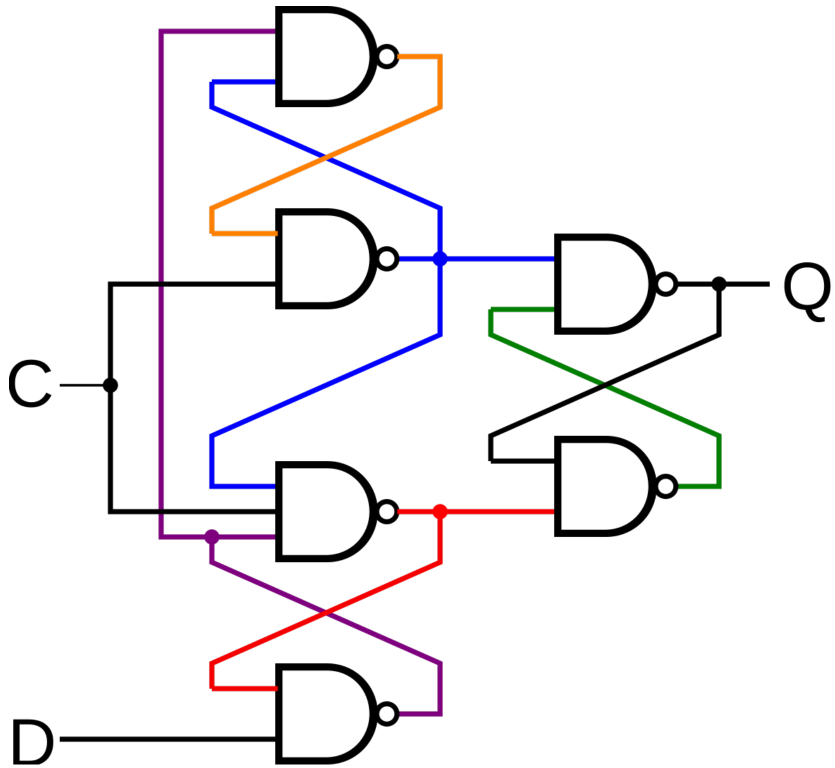
1-bit Register Circuit



1-bit Register Circuit



1-bit Register Circuit



Building a Counter

Any Questions?