Circuits and Code

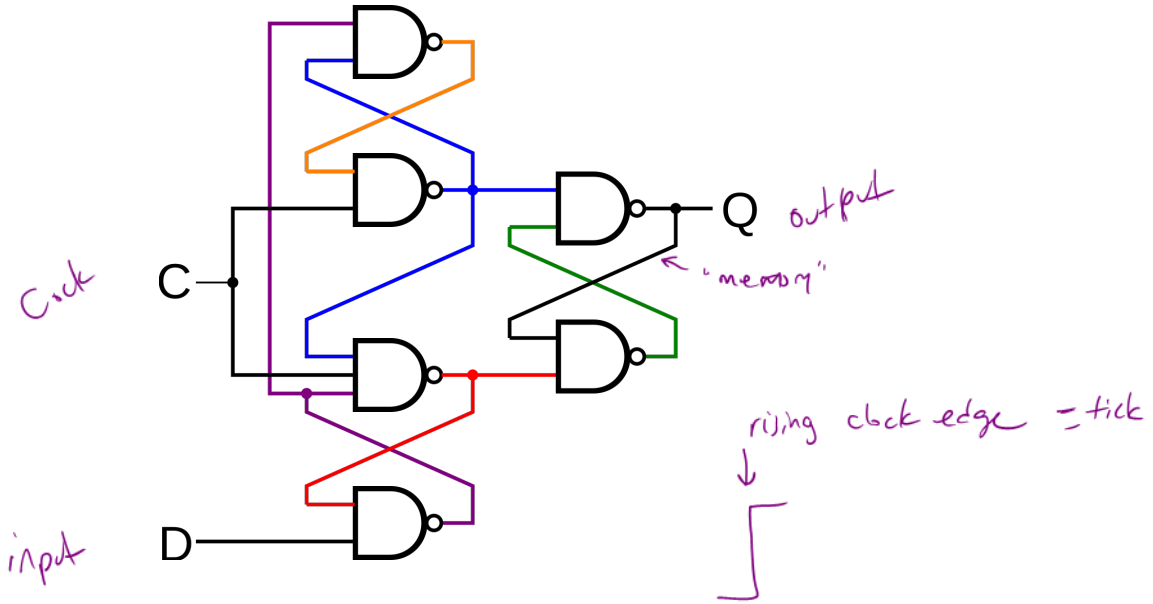
CS 2130: Computer Systems and Organization 1

February 6, 2023

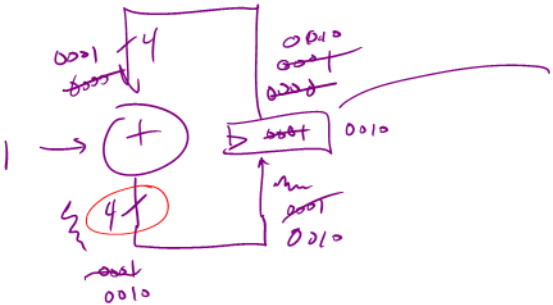
Announcements

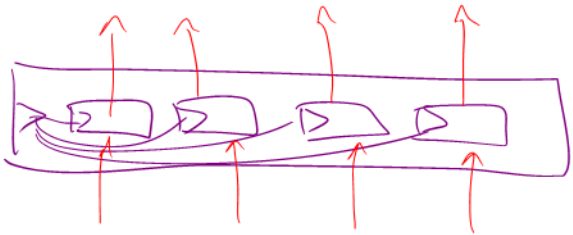
- Homework 1 due tonight
- Homework 2 available today online, due next Monday
  - Please react to the Discord message in #general today if you want me to bring a paper copy for you on Wednesday!

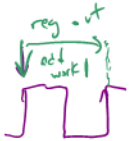
1-bit Register Circuit



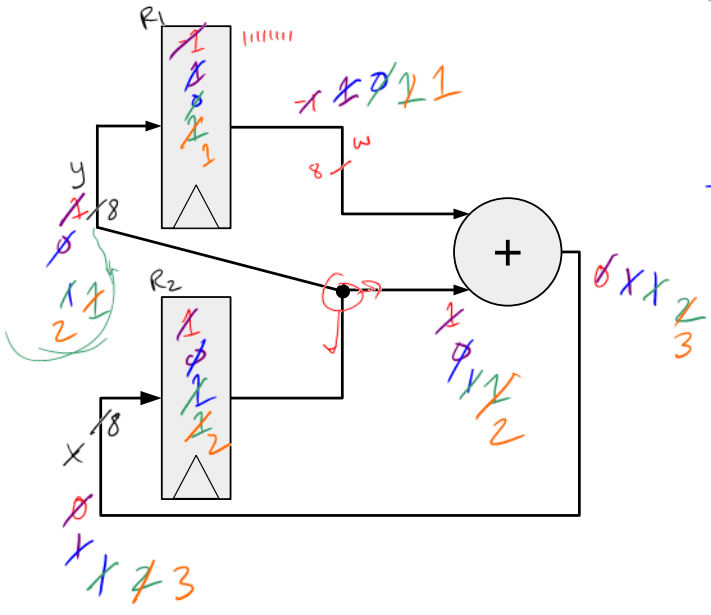
Building a Counter





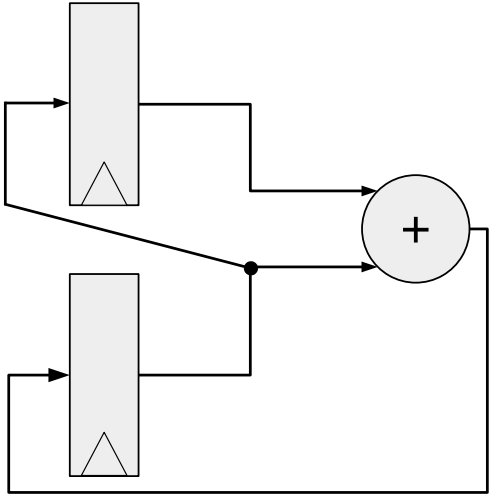


Another Circuit

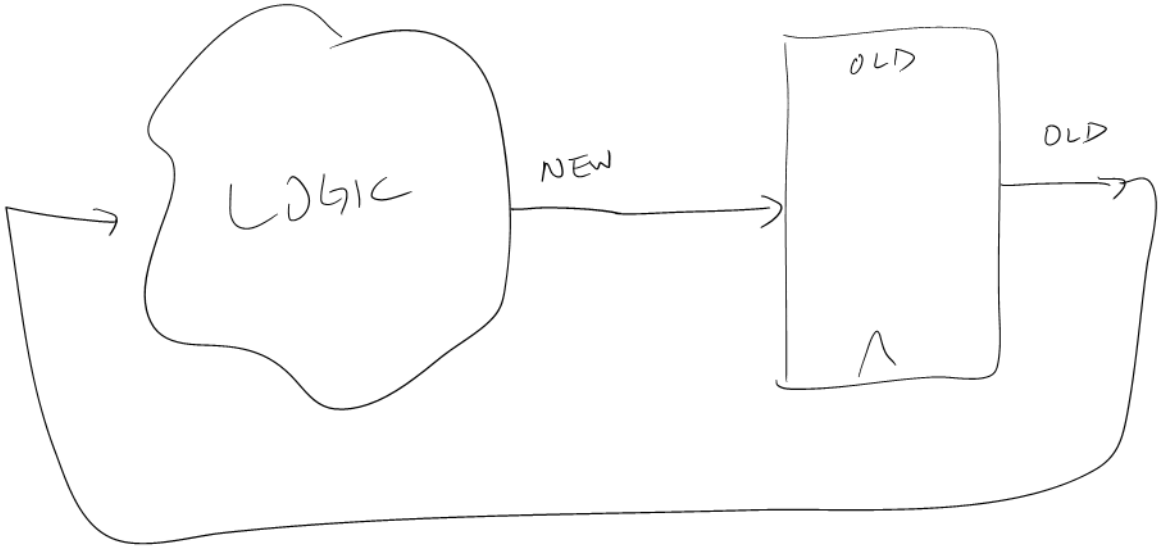


tick	x	y	R_1	R_2
0	0	1	-1	1
1	1	0	1	0
2	1	1	0	1
3	2	1	1	1
4	3	2	1	2
5	5	3		
6	8	5		
7	13	8		

Another Circuit



Common Model in Computers

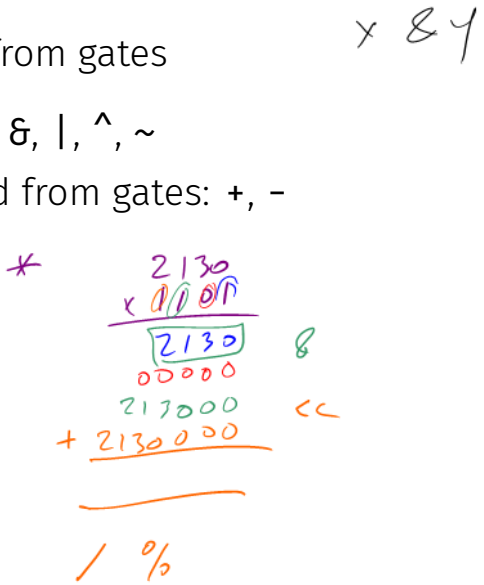


We can write code to build circuits

Code to Build Circuits from Gates

Write code to build circuits from gates

- Gates we *already* know: &, |, ^, ~
- Operations we can build from gates: +, -
- Others we can build:



Code to Build Circuits from Gates

Write code to build circuits from gates

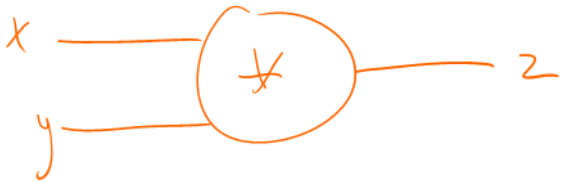
- Gates we *already* know: `&`, `|`, `^`, `~`
- Operations we can build from gates: `+`, `-`
- Others we can build:
- Ternary operator: `? :`

```
z = (a==b ? x : y) * w
```

Equals

Equals: `=`

- Attach with wire (i.e., connect things)
- Ex: `z = x * y`

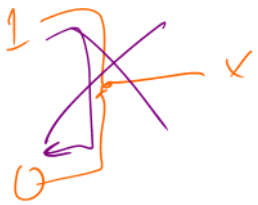


Equals

Equals: `=`

- Attach with wire (i.e., connect things)
- Ex: `z = x * y`
- What about the following?

```
x = 1
x = 0
```



Equals

Equals: `=`

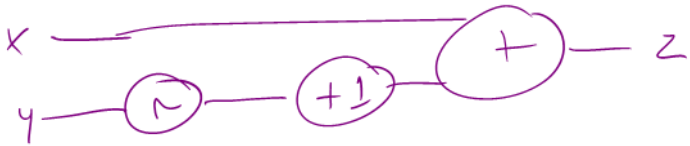
- Attach with wire (i.e., connect things)
- Ex: `z = x * y`
- What about the following?

  ```
  x = 1
  x = 0
  ```

- **Single assignment**: each variable can only be assigned a value once

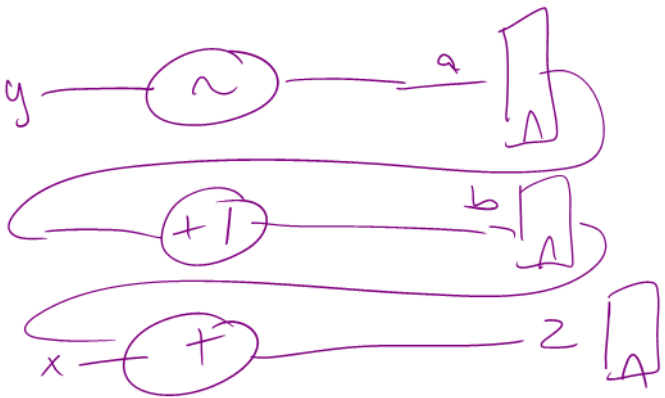
Subtraction

$z = x - y$




```
z = x + ~y + 1
```

```
a = ~y
b = a + 1
z = x + b
```



Comparisons

Each of our comparisons in code are straightforward to build:

- `==` - xor then nor bits of output

Comparisons

Each of our comparisons in code are straightforward to build:

- `==` - xor then nor bits of output
- `!=` - same as `==` without not of output

Comparisons

Each of our comparisons in code are straightforward to build:

- `==` - xor then nor bits of output
- `!=` - same as `==` without not of output
- `<` - consider `x < 0`

Comparisons

Each of our comparisons in code are straightforward to build:

- `==` - xor then nor bits of output
- `!=` - same as `==` without not of output
- `<` - consider `x < 0`
- `>`, `<=`, `=>` are similar

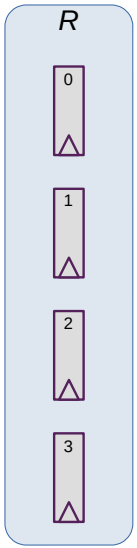
Indexing

Indexing with square brackets: `[ ]`

- **Register bank** (or **register file**) - an array of registers
  - Can programmatically pick one based on index
  - I.e., can determine which register while running
- Two important operations:
  `x = R[i]` - Read from a register
  `R[j] = y` - Write to a register

Reading

`x = R[i]` - connect output of registers to *x* based on index *i*

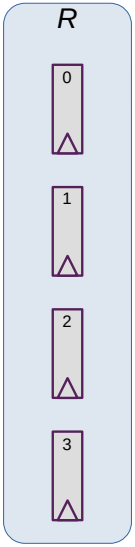


Aside: 4-input Mux

How do we build a 4-input mux? How many wires should *i* be?

Writing

`R[j] = y` - connect *y* to input of registers based on index *j*



Aside: Creating `==0` gates

How do we build gates that check for $j == w$?

Need one more thing to build computers

Memory and Storage

Registers ≈ KiB

- 6 gates each, ≈ 24 transistors
- Efficient, fast
- Expensive!
- Ex: local variables

Memory ≈ GiB

- Two main types: SRAM, DRAM
- DRAM: 1 transistor, 1 capacitor per bit
- DRAM is cheaper, simpler to build
- Ex: data structures, local variables

These do not persist between power cycles

Memory and Storage

Disk ≈ GiB-TiB

- Two main types: flash (solid state), magnetic disk
- Magnetic drive
  - Platter with physical arm above and below
  - Cheap to build
  - Very slow! Physically move arm while disk spins

- Ex: files

Data on disk does persist between power cycles

Putting it all together

Next time!