Circuits and Code

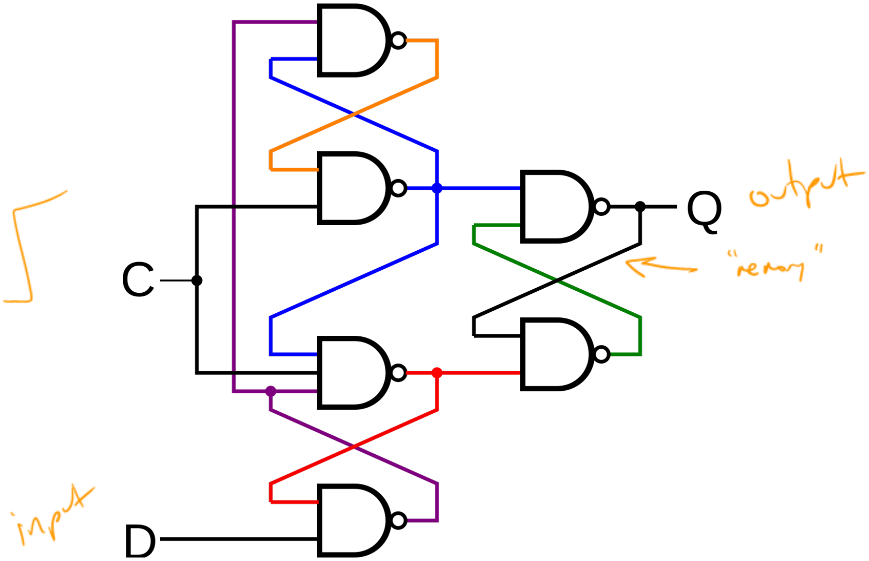
CS 2130: Computer Systems and Organization 1

February 6, 2023

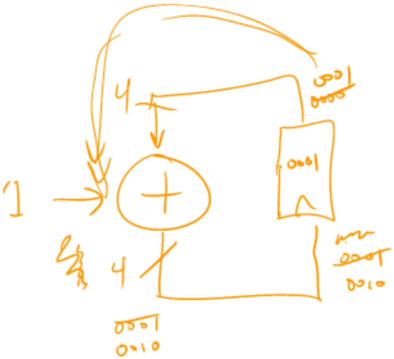
Announcements

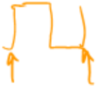
- Homework 1 due tonight
- Homework 2 available today online, due next Monday
    - Please react to the Discord message in #general today if you want me to bring a paper copy for you on Wednesday!

1-bit Register Circuit

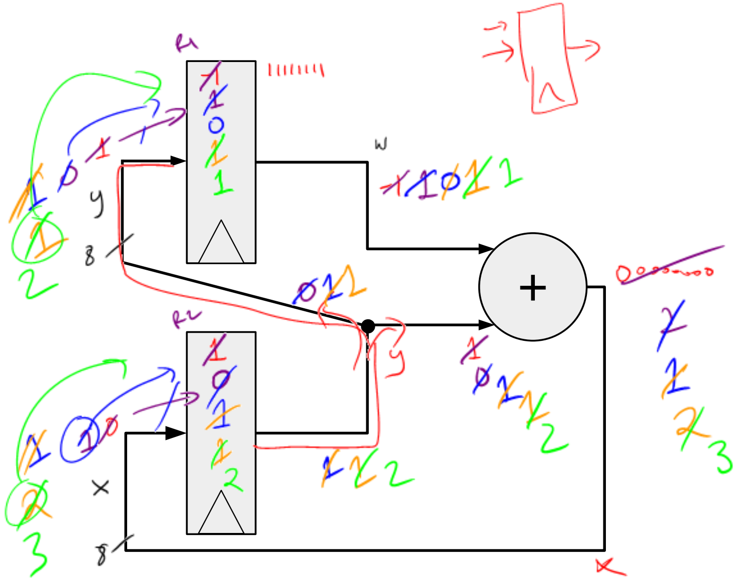


Building a Counter



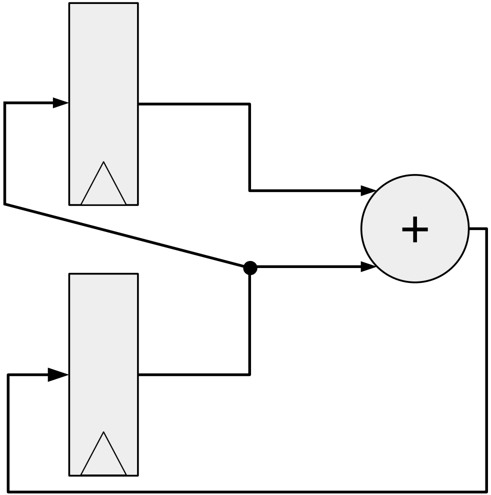


Another Circuit

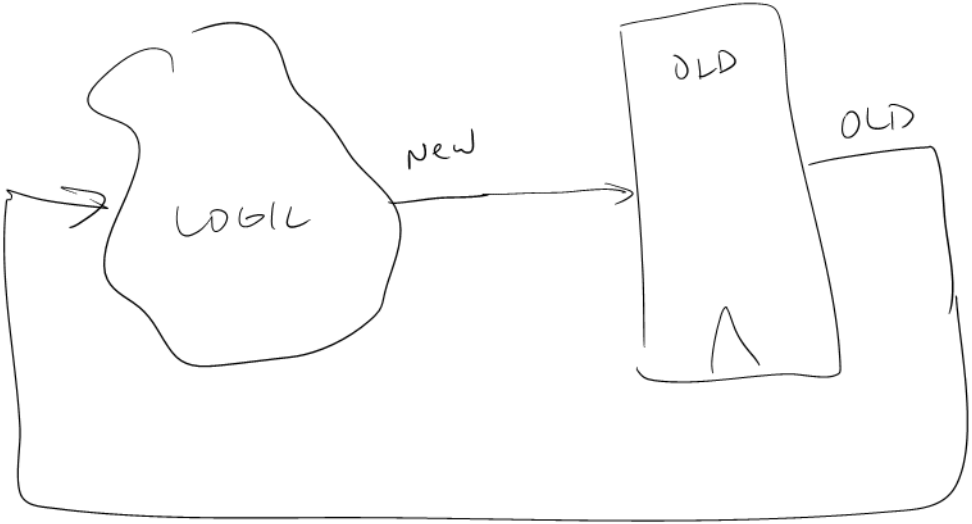


tick	x	y	R1	R2
0	0	1	-1	1
1	1	0	1	0
2	1	1	0	1
3	2	1	1	1
4	3	2	1	2
5	5	3		
6	8	5		
7	13	8		

Another Circuit



Common Model in Computers



We can write code to build circuits

Code to Build Circuits from Gates

$\underline{x \,\&\, y}$

Write code to build circuits from gates

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

$$\begin{array}{rl}
2130 & \\
\times \quad 1001 & \\
\hline
2130 & \& \\
00000 & \\
213000 & \ll \\
2130000 & \\
\hline
+ \qquad\qquad & \\
\hline
\end{array}$$

/ , %

Code to Build Circuits from Gates

Write code to build circuits from gates

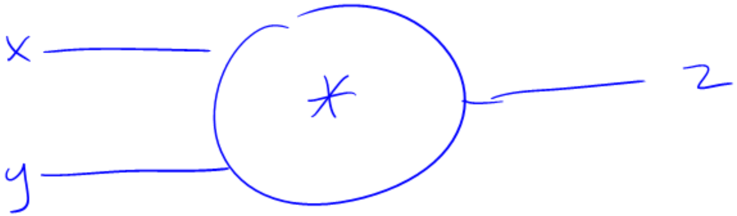
- Gates we *already* know: &, |, ^, ~
- Operations we can build from gates: +, -
- Others we can build:
- Ternary operator: ? :

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

Equals

Equals: `=`

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

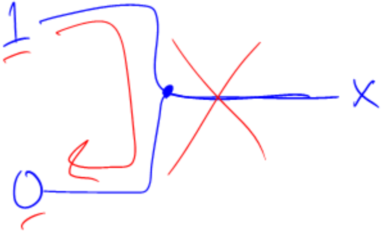


Equals

Equals: `=`

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

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



Equals

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

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  x = 1
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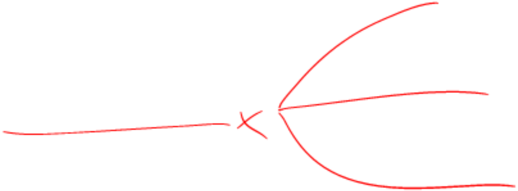
  ```

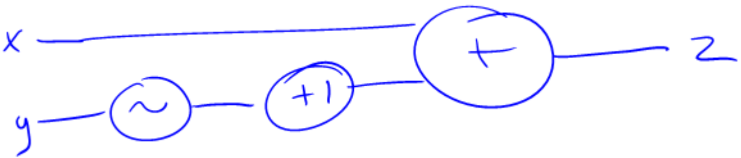
- **Single assignment**: each variable can only be assigned a value once



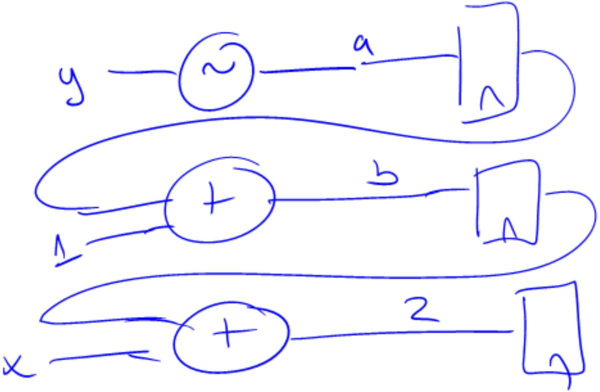
Subtraction

z = x - y

$$z = x + \overbrace{\sim y + 1}^{-y}$$



```
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

x == y

~ (orbits

! (x ^ y))

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- `==` - xor then nor bits of output
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- `<` - consider `x < 0`

$(x >> 31) \& 1$

$x < y \quad x - y < 0$

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: `[ ]`

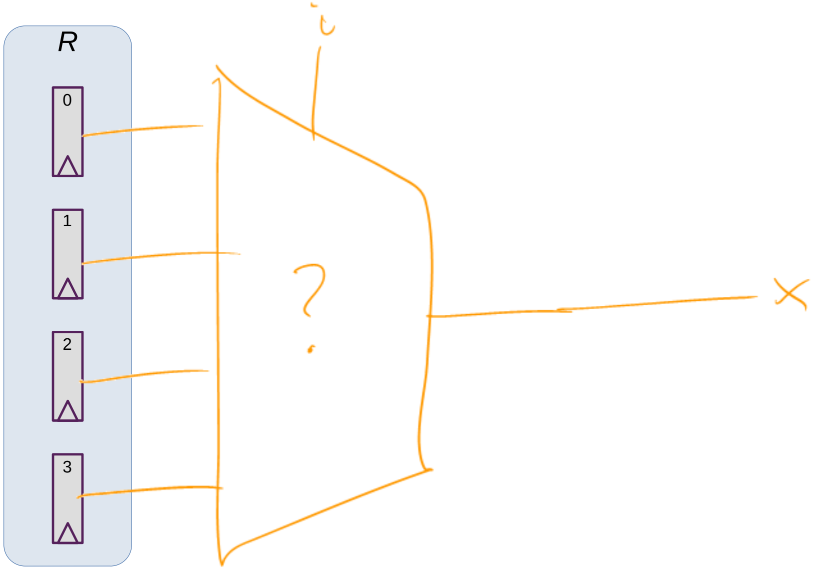
- **Register bank** (or **register file**) - an array of registers
  - Can programmatically pick one based on index
  - I.e., can determine which register while running
- Two important operations:

  `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*

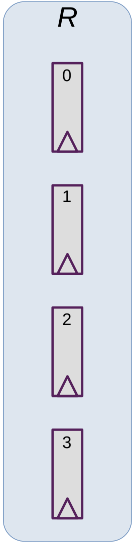


Aside: 4-input Mux

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 $\approx$ KiB

- 6 gates each, $\approx$ 24 transistors
- Efficient, fast
- Expensive!
- Ex: local variables

Memory $\approx$ 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 $\approx$ 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!