Fav sitcom out of Prof. Schatz's favorites

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Q1

~Code~

340

CS 340

Building Blocks 0b10
(Selection and Information Storage)

Updates

1. MP 2 - due next Tuesday.
2. HW 3 due next Thursday 1:59pm
   a. Building Blocks
   b. If you need help with gates (see video posted on campus wire and the website)
3. Exam 1 - September 23rd
   a. Sign up now! By the 18th.

Tuesday - no class

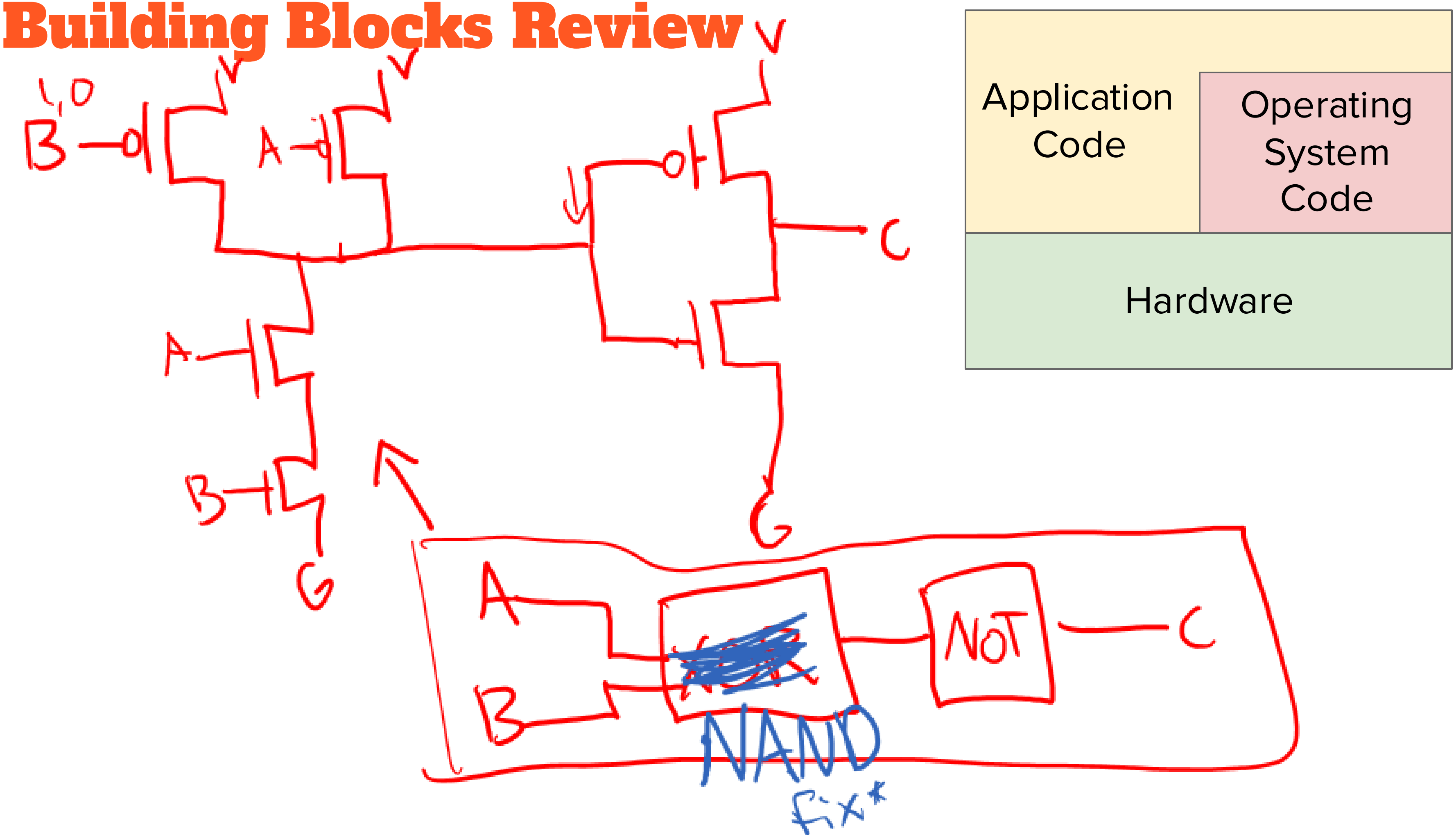
mp0 - mp2

Building Blocks 0b10

Today's LGs:

- Be convinced you can use gates to build calculations and selection.
- Have a brief understanding of why we use base-2 for storage
- Be able to articulate that
  - Computers have different types of storage hardware
  - We utilize the different types of storage by using caching
  - Caching algorithms rely on spatial and temporal locality
- Be able to identify if code is cache friendly or not

Building Blocks Review



Application Code

Operating System Code

Hardware

Building Blocks

1. Circuit Basics
2. Gates
3. Binary
4. **Arithmetic Computations**
5. **Selection**
6. **Storage**

Arithmetic Calculations

Arithmetic Calculations in Logic

$5+3=8 \Rightarrow 2$

$x=5=\underbrace{0101}_{x_3\, x_2\, x_1\, x_0}$

$y=3=\underbrace{0011}_{y_3\, y_2\, y_1\, y_0}$

$$\begin{array}{rcccc} & 1 & 1 & 1 & \\ & 0 & 1 & 0 & 1 \\ + & 0 & 0 & 1 & 1 \\ \hline & 1 & 0 & 0 & 0 \end{array}$$

$$\begin{array}{c|cccc} x & 0 & 1 & 0 & 1 \\ y & 0 & 0 & 1 & 1 \\ \hline z & 1 & 0 & 0 & 0 \\ & z_3 & z_2 & z_1 & z_0 \\ \hline c & 0 & 1 & 1 & 0 \\ & & & c_1 & c_0 \end{array}$$

$z_0 = x_0 \wedge y_0$

$z_0 = 1 \wedge 1$

$z_0 = 0$

$c_1 = x_0 \,\&\, y_0$

$c_1 = 1 \,\&\, 1 = 1$

$z_i = c_i \wedge x_i \wedge y_i$

$c_{i+1} = (x_i \,\&\, y_i) \,|\, (c_i \,\&\, (x_i \wedge y_i))$

Arithmetic Calculations in Logic

$Z_0 = x_0 \hat{}\, y_0$

$C_1 = x_0 \& y_0$

$Z_i = C_i \hat{}\, x_i \hat{}\, y_i$

$C_{i+1} = (x_i \& y_i) \mid (c_i \& (x_i \hat{}\, y_i))$

Arithmetic Calculations in Hardware

$Z_0 = x_0 \hat{} y_0$

$C_1 = x_0 \,\&\, y_0$

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Q2

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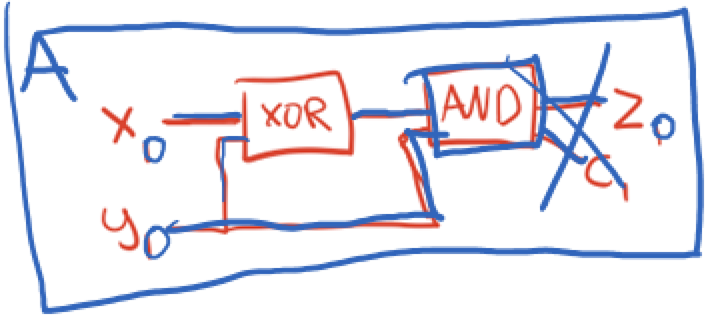
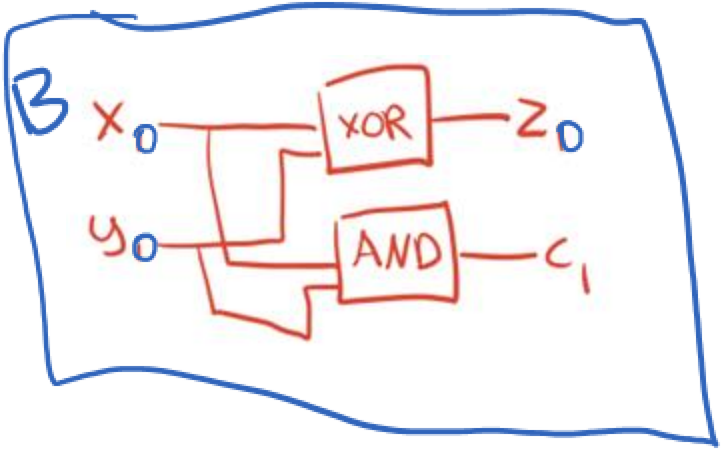
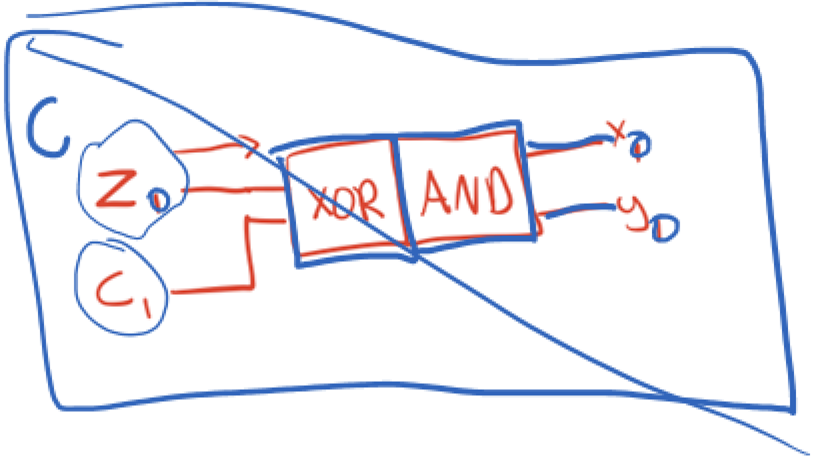
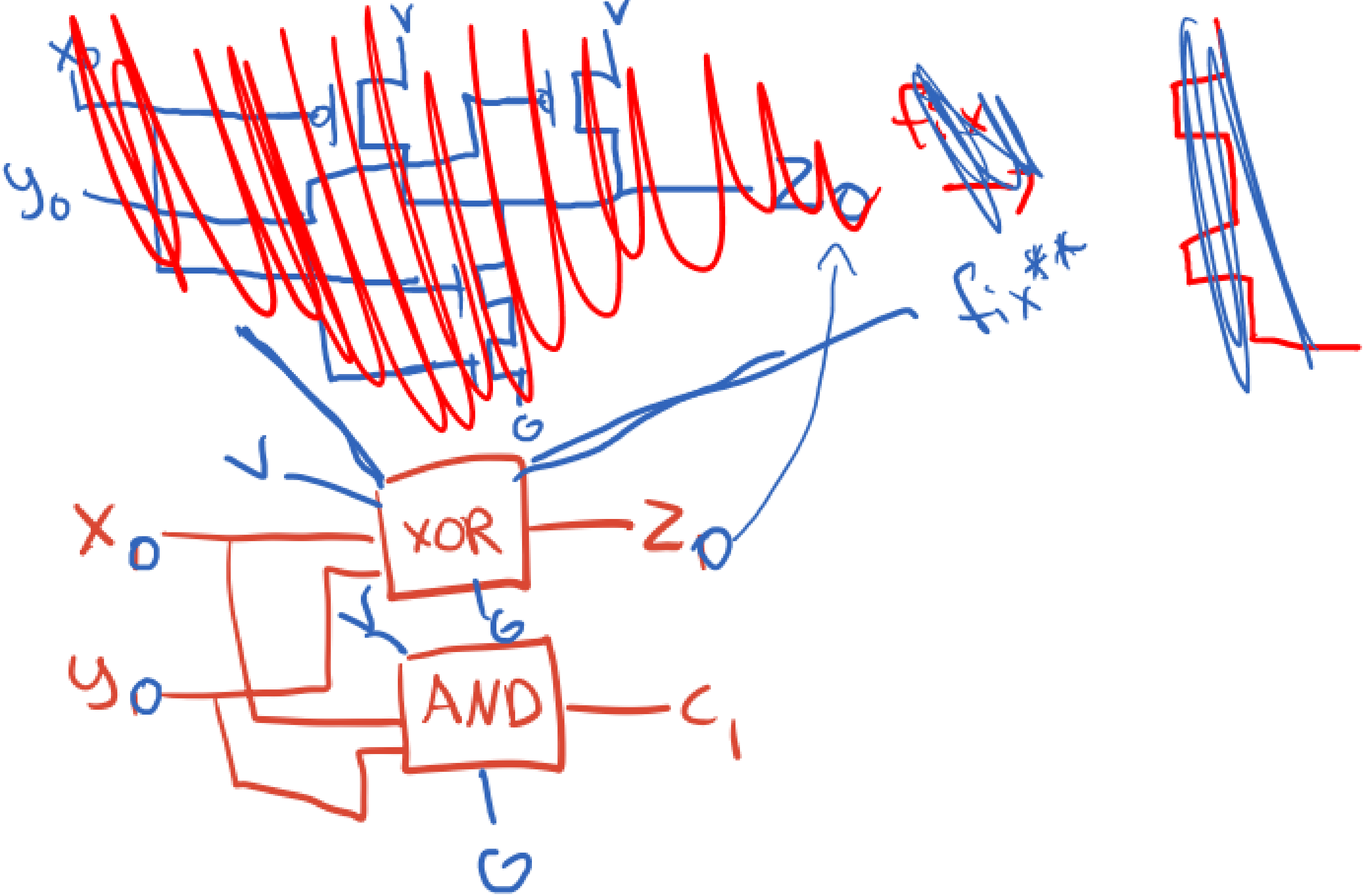






Arithmetic Calculations in Hardware



What is Z?

$Z_0 = x_0 \wedge y_0$

$C_1 = x_0 \& y_0$

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Q3

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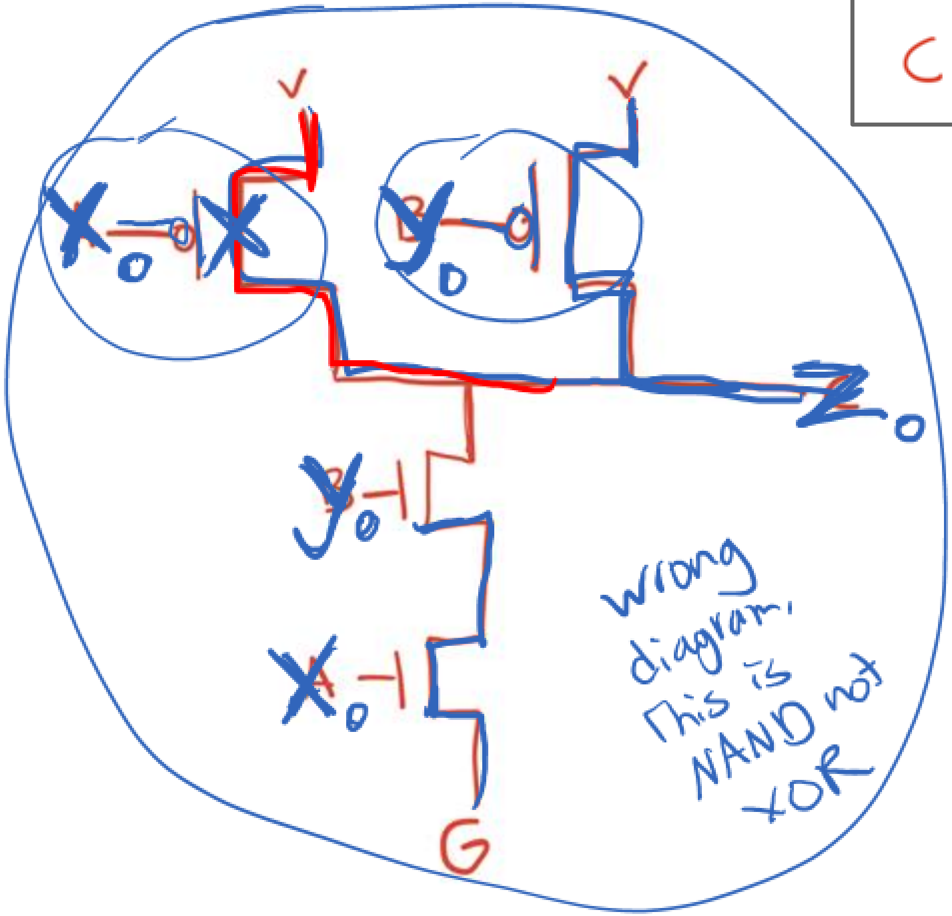

wrong diagram, this is NAND not XOR

$x_0 \quad y_0$

$\underline{1+0} = Z_0 ?$

$0+0 = \boxed{1}$

Selection

MUX (sounds like ducks with an m)

$[\overset{0}{\underset{0}{a}}, \overset{1}{\underset{1}{b}}]$ $s = {}^{0 \text{ or } 1}$

$$(\neg s \,\&\, a) \,||\, (\overset{1\,\&\,1}{s \,\&\, B})$$

if $s = 1$ $0 \,\&\, a$

$(0) \,||\, 1$

$= 1, b$

What is the output?

[a, b]
0 1

S = 0 or 1

(¬s & a) | (s & B) =

S = 0

[1, 1]
A B
0 1

(1 & 0) | (0 & 1)
0 1 0 = 0

(1 & 1) | (0 & 1)
1 1 0 = 1

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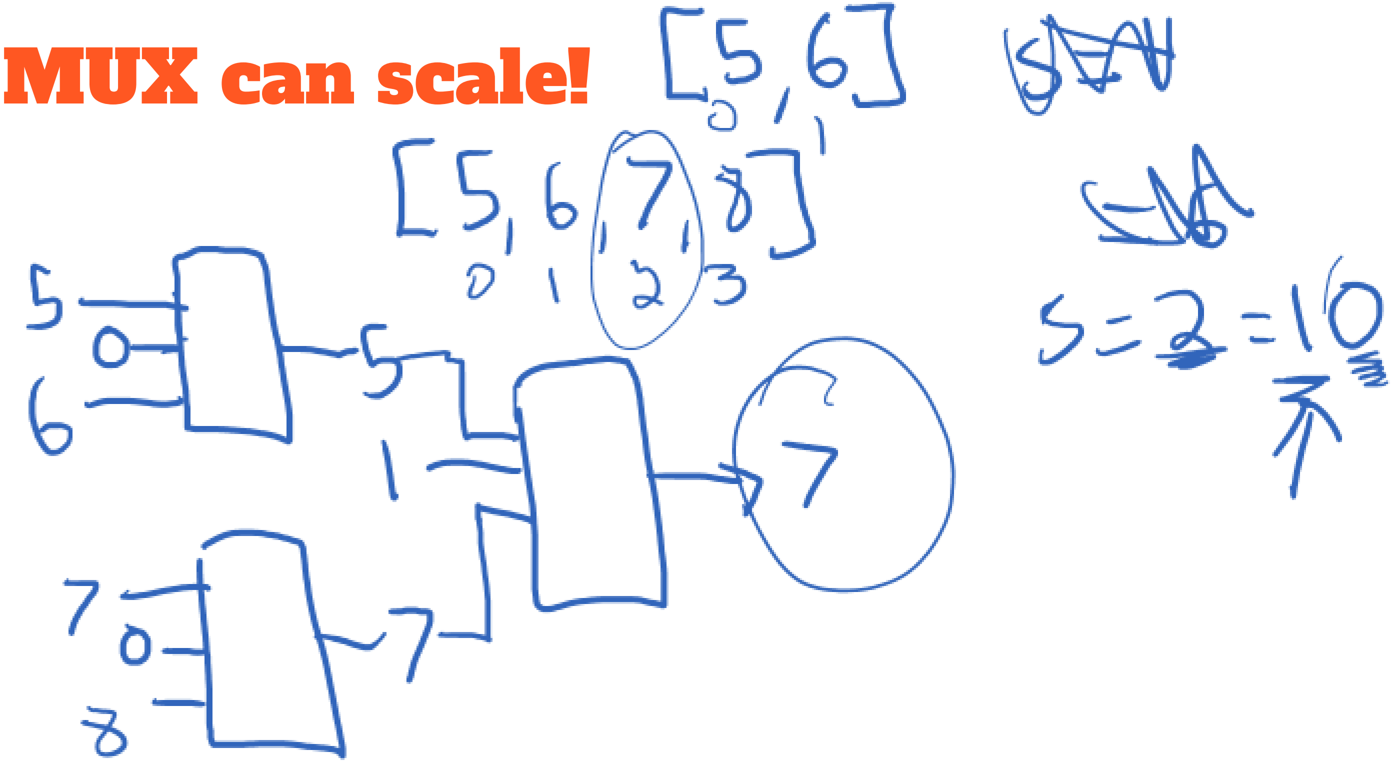
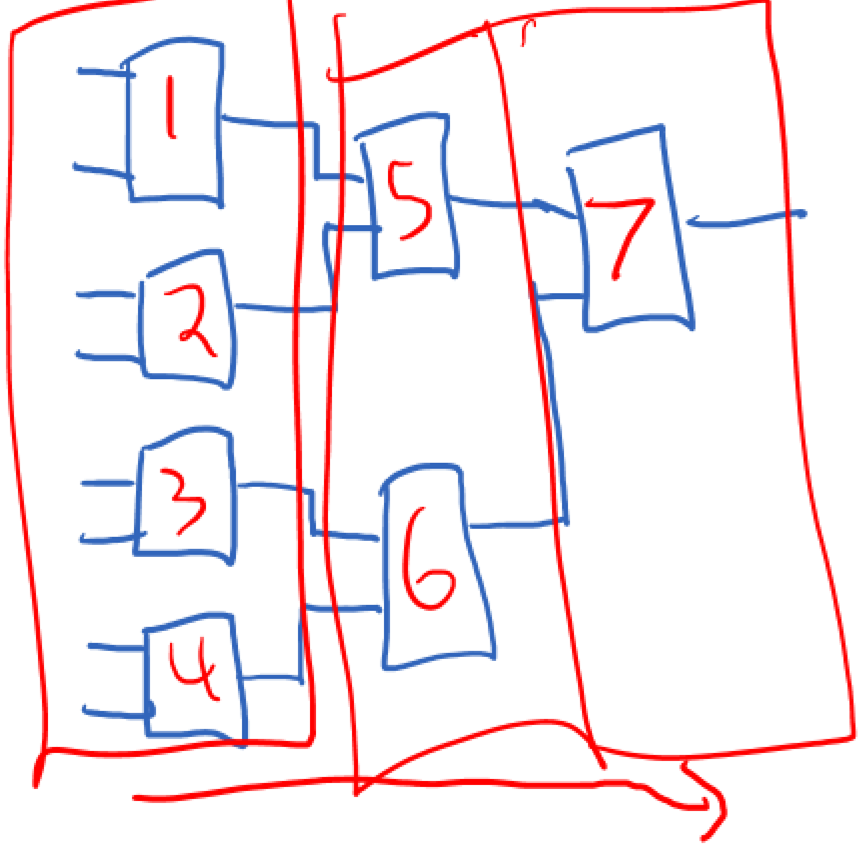
MUX can scale!



How many 2-MUX for a 8 selection?



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depth = 3

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Q5

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What depth of 2-MUX's for a 16 input selection?

$\log_2 16 = 4$

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Q6

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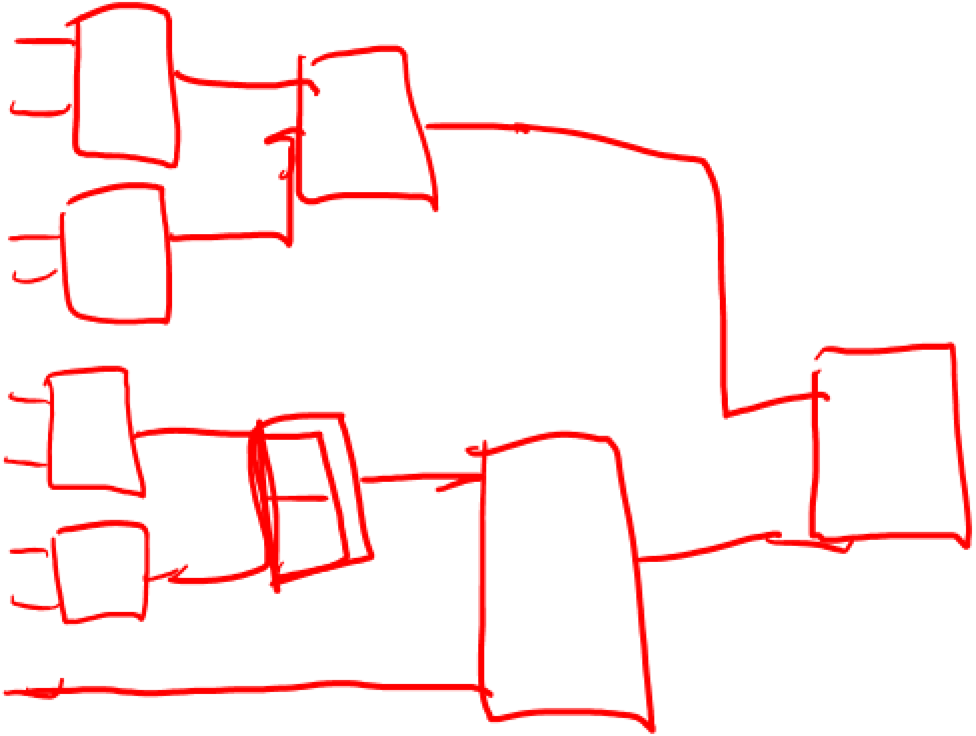
What depth of 2-MUX's for a 9 input selection?



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MUX Takeaways

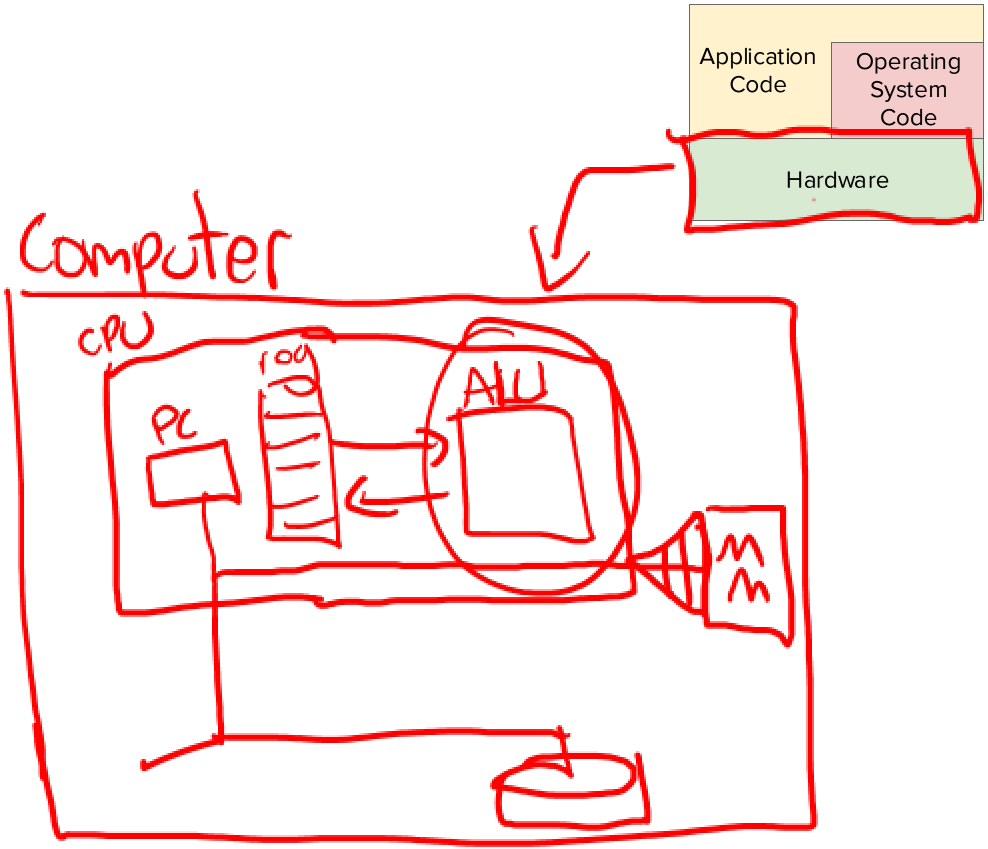
selects 1 from many

more depth = bad

slower

Summary Slide

1. Circuit Basics
2. Gates
3. Binary
4. Arithmetic Computations
5. Selection
6. **Storage**



Application Code

Operating System Code

Hardware

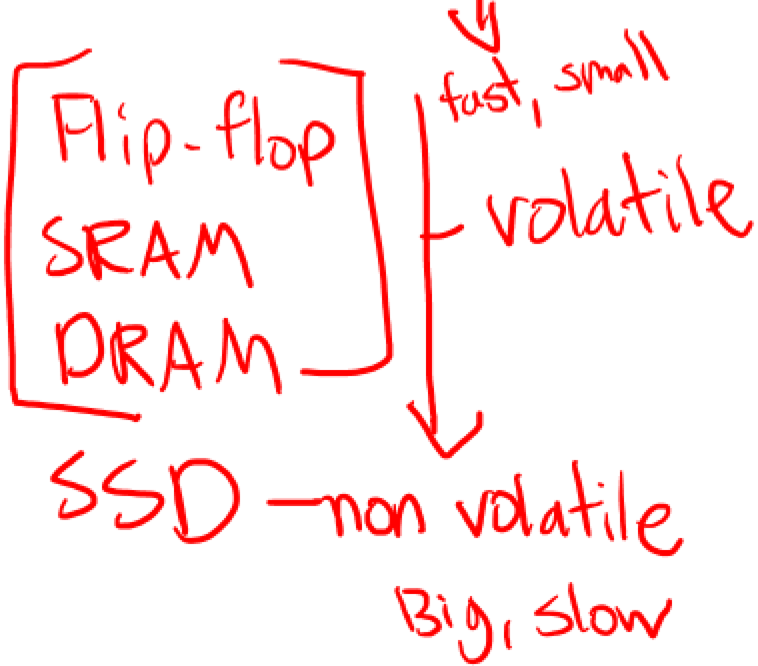
Storage

Hardware for Storing Information

store 1 or 0

volatile - goes away when off

non volatile → stay when off



fast, small

Flip-flop

SRAM

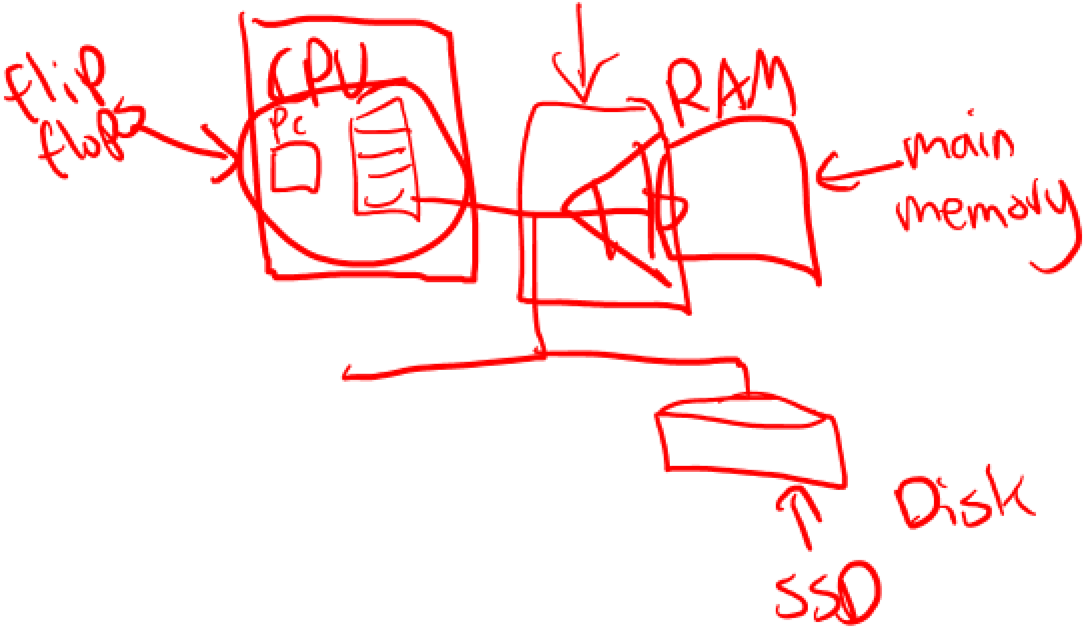
DRAM

volatile

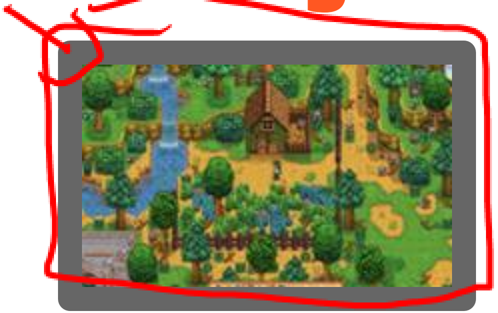
SSD - non volatile

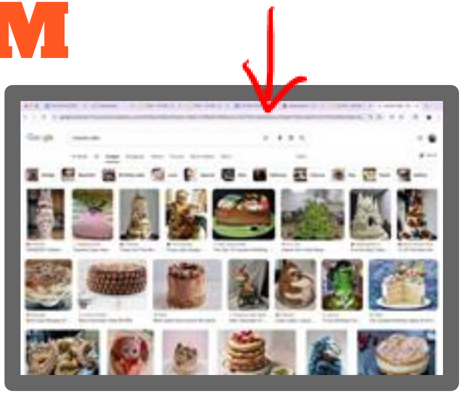
Big, slow

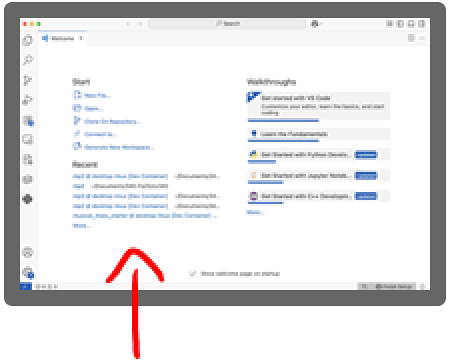
Hardware for Storing Information



Caching RAM







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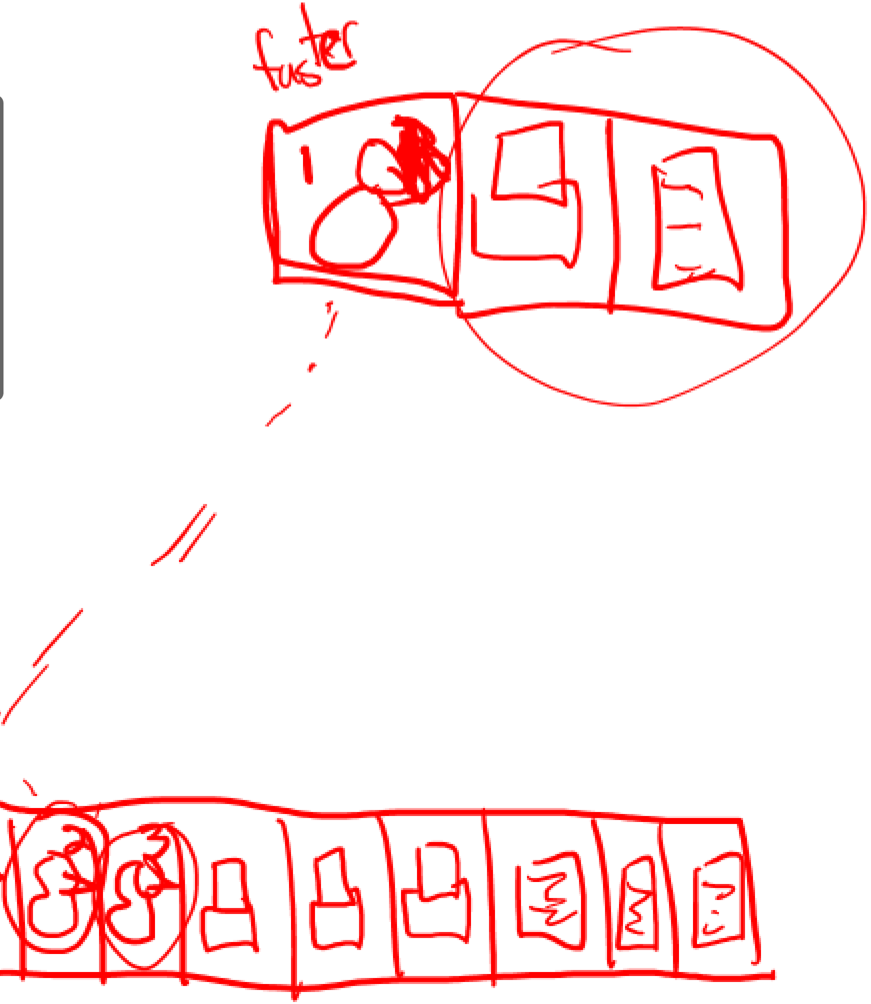
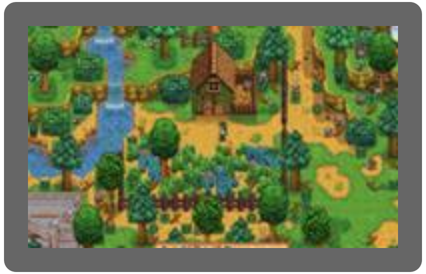
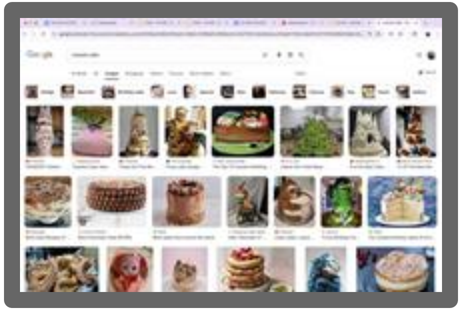
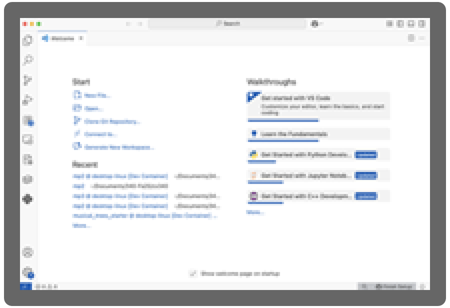


Caching RAM



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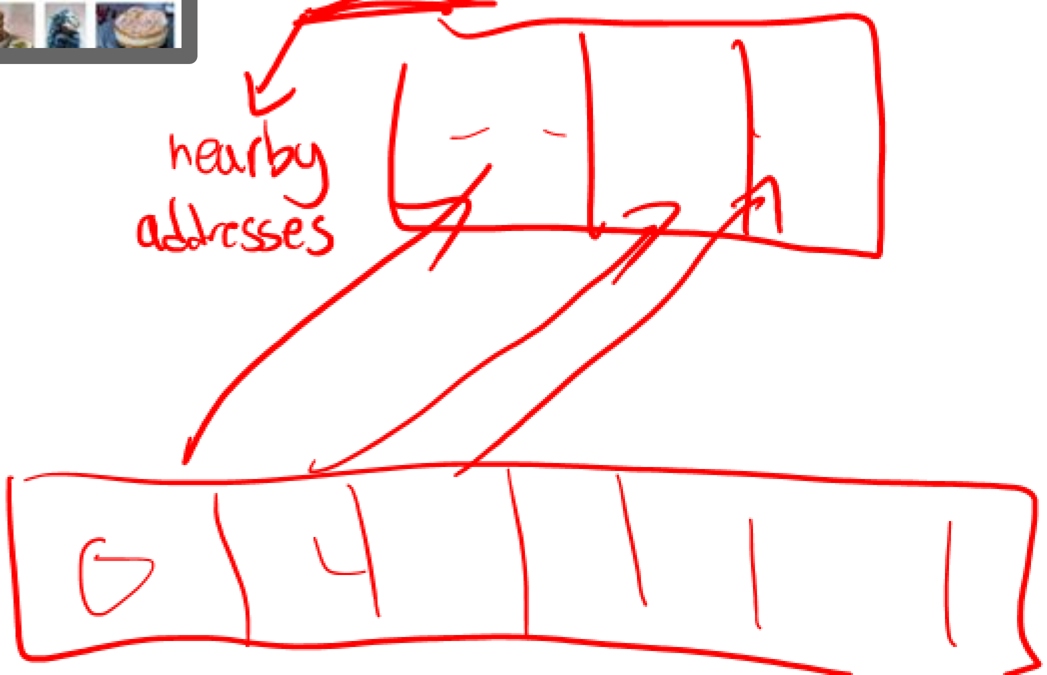
what is most likely

Locality

reuse things

temporal ← time

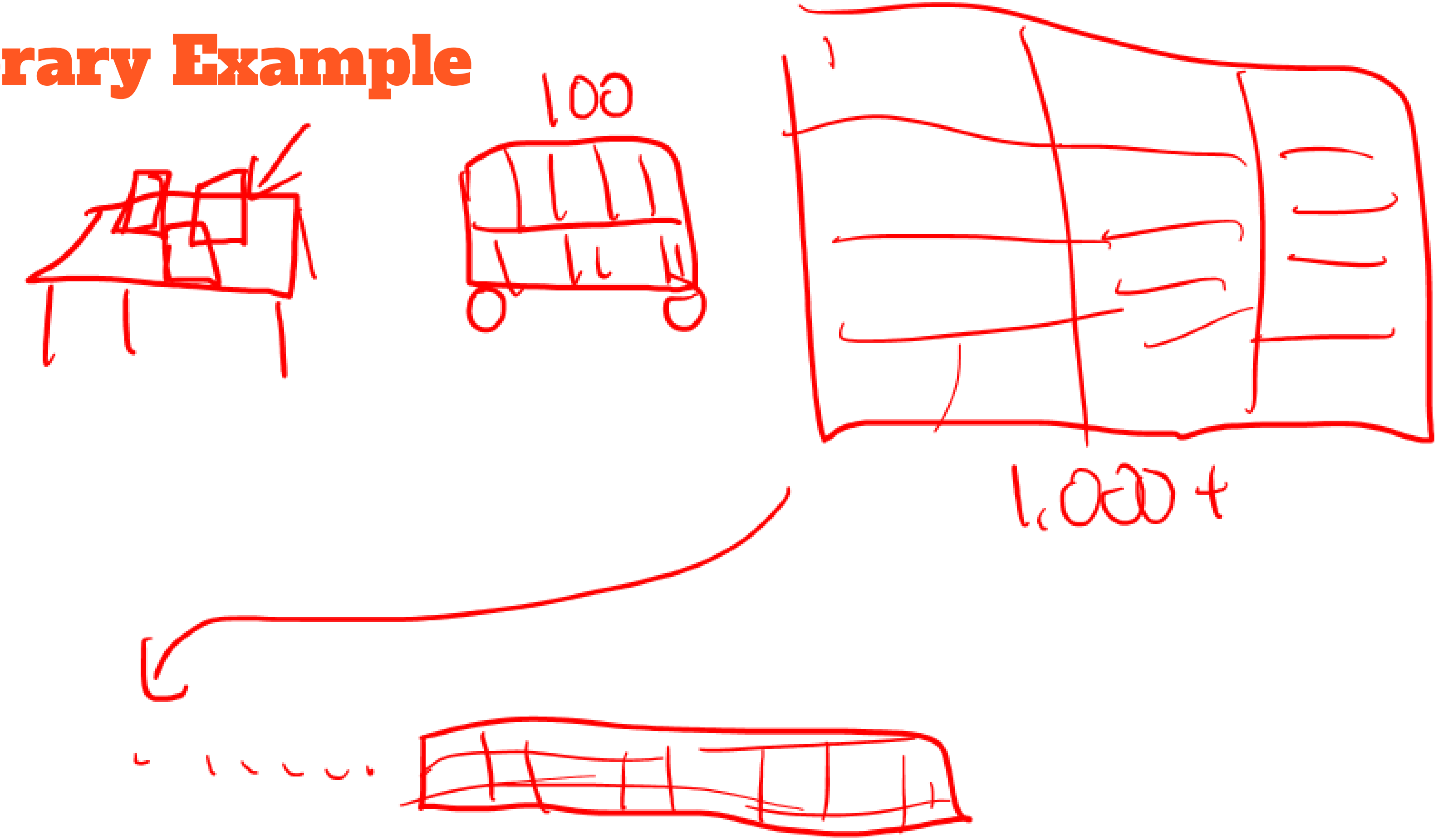
spatial ← space



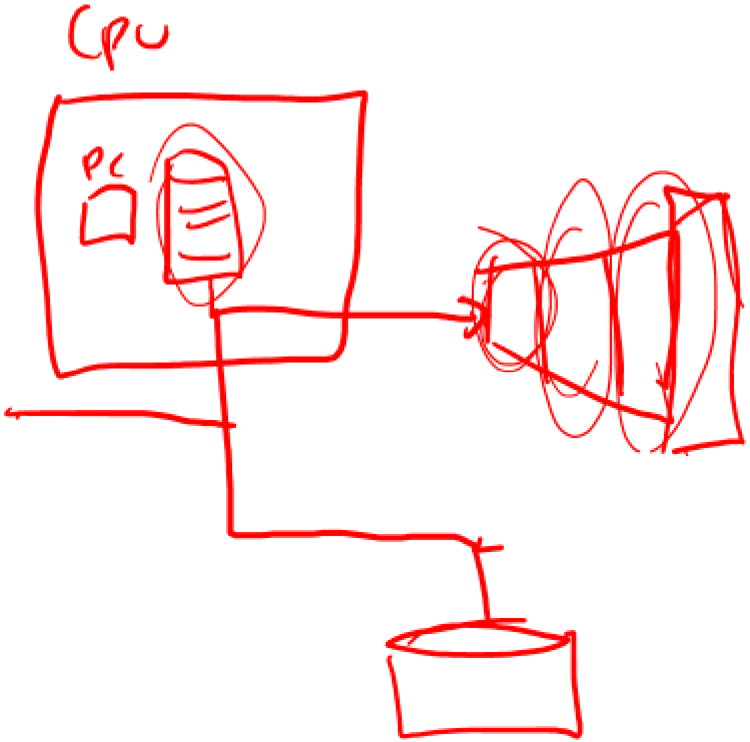
Caching - an algorithm for utilizing fast and small memory and ~~small~~ slow big memory. We keep copies in higher levels for quick access

Locality - the idea that computers often use nearby and similar information sequentially. Local and temporal locality.

Library Example



Computer Information Storage



Can you change this code for better locality?

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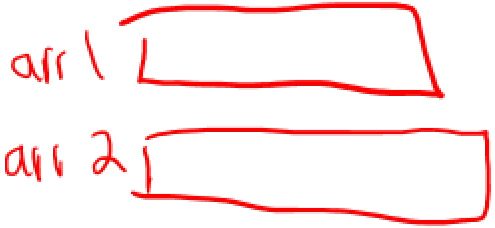

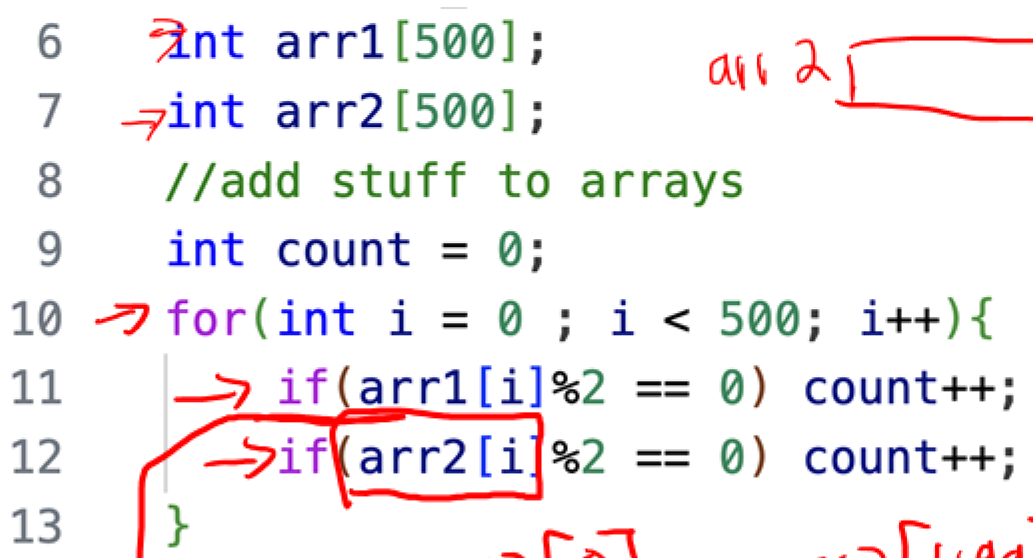

```
int arr1[500];
int arr2[500];
//add stuff to arrays
int count = 0;
for(int i = 0 ; i < 500; i++){
    if(arr1[i]%2 == 0) count++;
    if(arr2[i]%2 == 0) count++;
}
```

arr2
~~arr~~
~~arr2~~
~~arr1~~
500

for

arr2[0] arr2[499]

*(arr2+0) *(arr2+499)

Can you change this code for better locality?

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Q9

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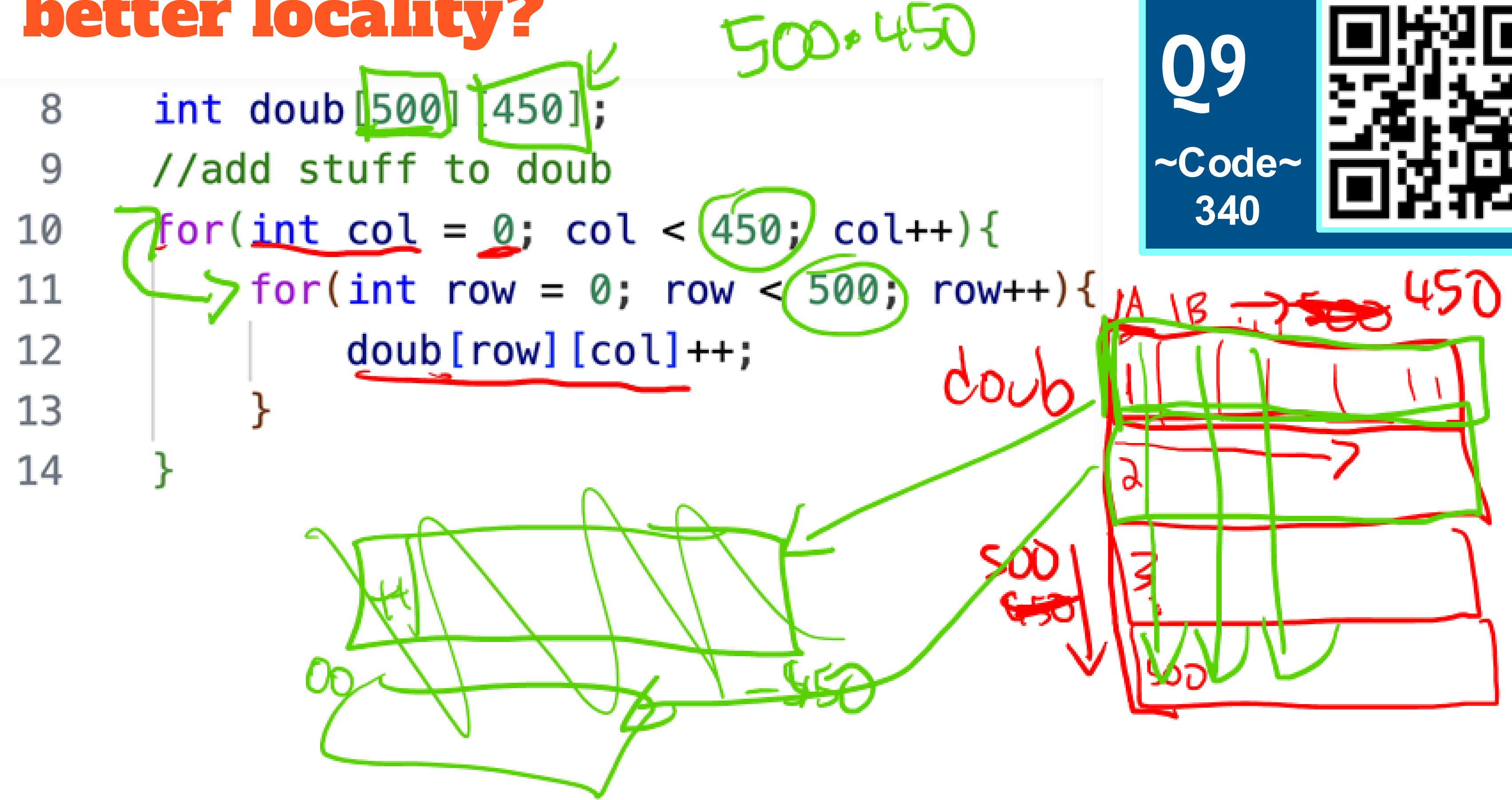

```
int doub[500][450];
//add stuff to doub
for(int col = 0; col < 450; col++){
    for(int row = 0; row < 500; row++){
        doub[row][col]++;
    }
}
```

Building Blocks

1. Circuit Basics
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