CSCI 210: Computer Architecture
Lecture 36: Caches V

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CS History: IBM System/360 Model 85

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- First computer to have cached memory
- Shipped in December of 1969
- Had either 16 KB or 32 KB cache
  - Modern systems have around 64 MB
- IBM only built about 30 of them

CACHE SIMULATOR PROJECT

Cache Simulator

- Take in a datatrace of load/stores from a real program
- Simulate running the program on a given cache
- Calculate how well a given cache would perform for that trace

Cache Parameters

- Always: Write-allocate, write-back, LRU replacement

- Change:
  - Cache size
  - Block size
  - Associativity
  - Miss penalty

Address Trace

Load/Store Address InstructionCount

```
# 0 7fffed80 1
# 0 10010000 10
# 0 10010060 3
# 1 10010030 4
# 0 10010004 6
# 0 10010064 3
# 1 10010034 4
```

L/S: 0 for load, 1 for store

Simulation Results

```
Simulation results:
    execution time                 52268708 cycles
    instructions                    5136716
    memory accesses                 1957764
    overall miss rate                  0.79
    load miss rate                     0.88
    CPI                               10.18
    average memory access time        24.07 cycles
    dirty evictions                  225876
    load_misses                     1525974
    store_misses                      30034
    load_hits                        205909
    store_hits                       195847
```

What do you need to do?

- Create data structures that emulate a cache
- For each load/store instruction, find where the data would go in the cache, check if it’s already there
- Update cache metadata when cache blocks get evicted
- Calculate number of miss penalty cycles, load misses, store misses, instructions, etc.

Implementation hints

- Create a data structure that contains all of the metadata you need to keep for one cache entry (valid bit, dirty bit, tag) to keep this data in one place; don't keep a vector of valid bits, a vector of dirty bits, and a vector of tags for example
- Create a data structure that keeps track of a set of cache entries and the LRU metadata for the set
- Keep track of counts of events (instructions, misses, hits, dirty evictions, etc.) not statistics; e.g., don't have a CPI field
- Compute the statistics from the counts

Questions on Cache Final Project?

We have an 8 byte block size, direct-mapped, 16 kB cache. For a given byte address, to find the offset

A. Mod by 8

B. Mod by 16

C. Divide by 8

D. Divide by 16

E. None of the above

If we are simulating a cache and not actually accessing data, do we need to use the offset for anything?

A. Yes

B. No

We have an 8 byte block size, direct-mapped, 16 kB cache. How many rows will this cache have?

A. 16

B. 2*1024

C. 8*1024

D. 16*1024

*Recall a kB is 1024 bytes

We have an 8 byte block size, direct-mapped, 16 kB cache. How can we find the index from an address?

A. Divide by 8

B. Divide by (16*1024)

C. Mod by 16*1024

D. Divide by 8, then mod by (2*1024)

E. None of the above

We have an 8 byte block size, 2-way set associative, 16 KB cache. How can we find the index from an address?

A. Divide by 8, then mod by 1024

B. Divide by 8, then mod by (2*1024)

C. Divide by 8, then mod by (2*2*1024)

D. Divide by 16, then mod by (2*1024)

E. None of the above

We have an 8 byte block size, direct mapped, 16 KB cache. How can we find the tag of an address?

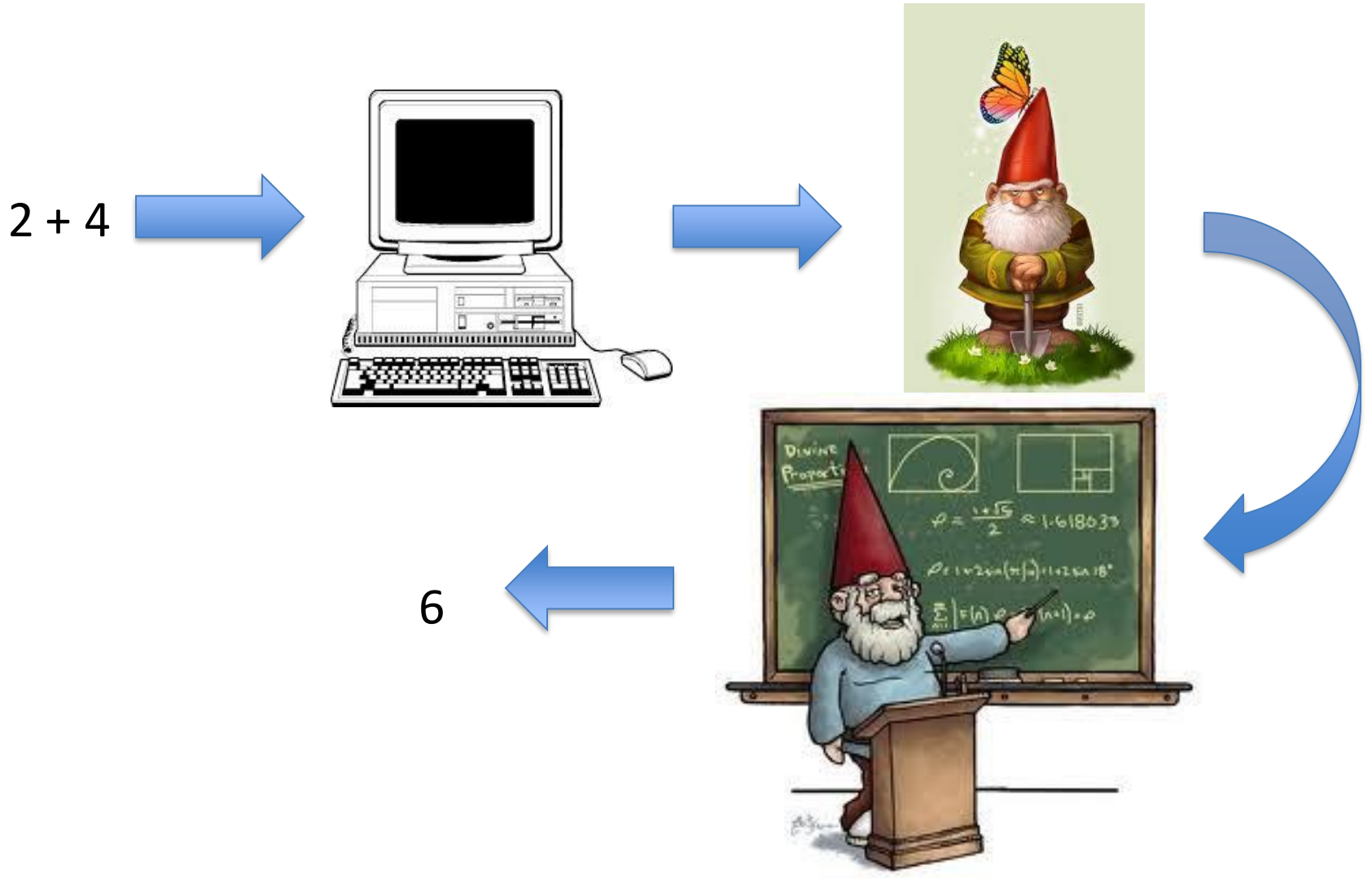
A. Divide by 8

B. Divide by 8 * 1024

C. Divide by 16*1024

D. None of the above

Previous Conceptions of How Computers Work



Actually Assembly

High Level:

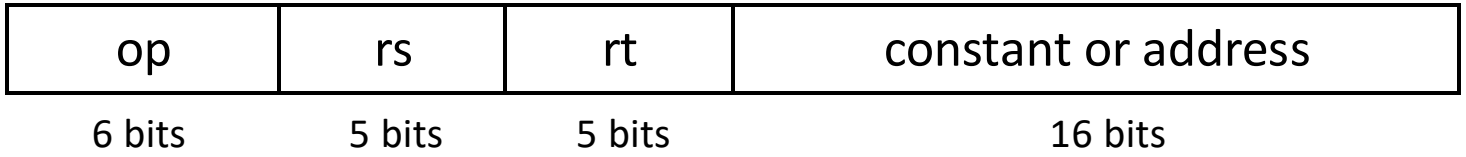
```
x = 2 + 4
```

Assembly (assuming we have a mem address for x in $s0):

```
li      $t1,  2
addi    $t1, $t1, 4
sw      $t1, 0($s0)
```

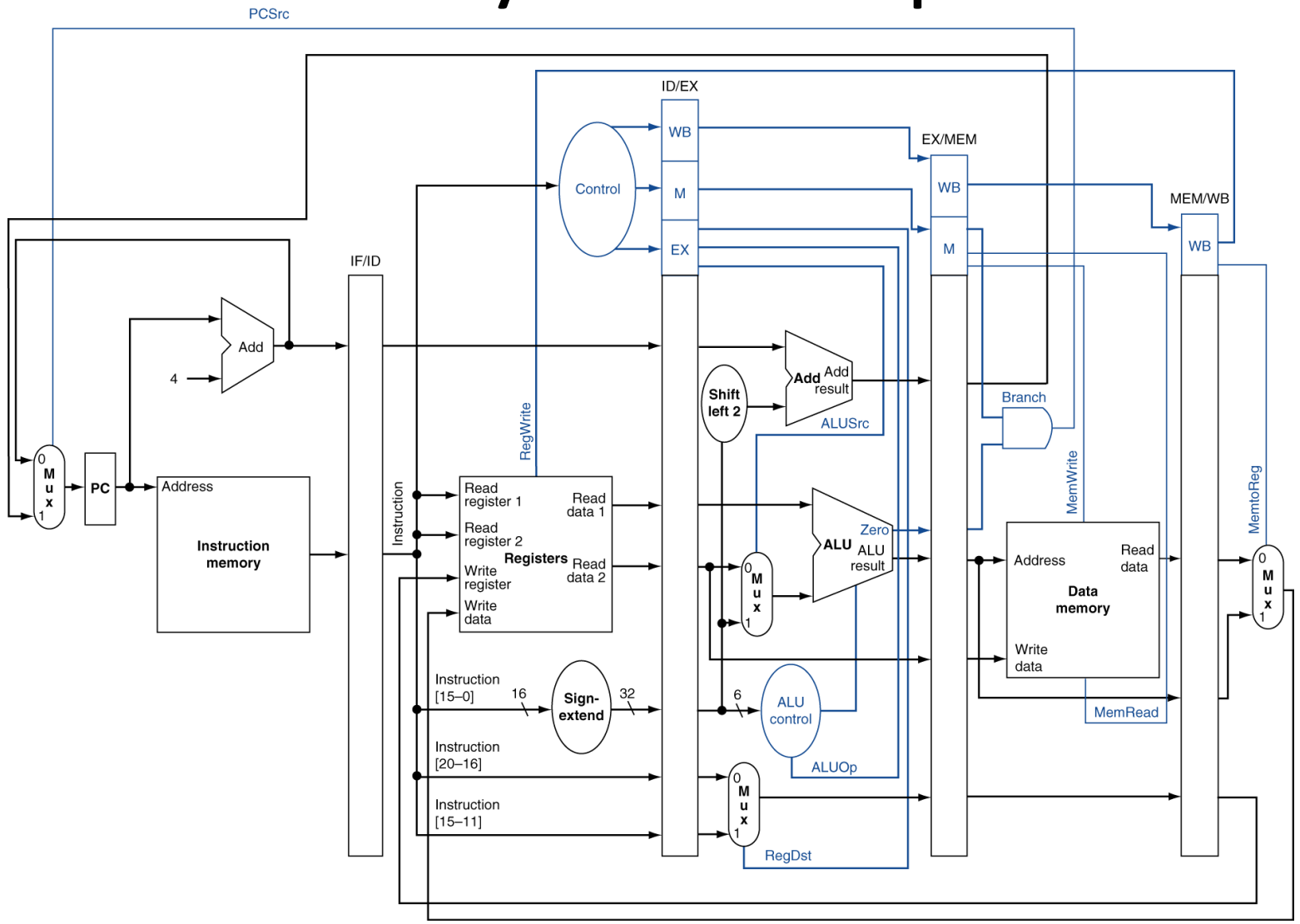
Actually Machine Instructions

```
addi $t1, $t1 5
```

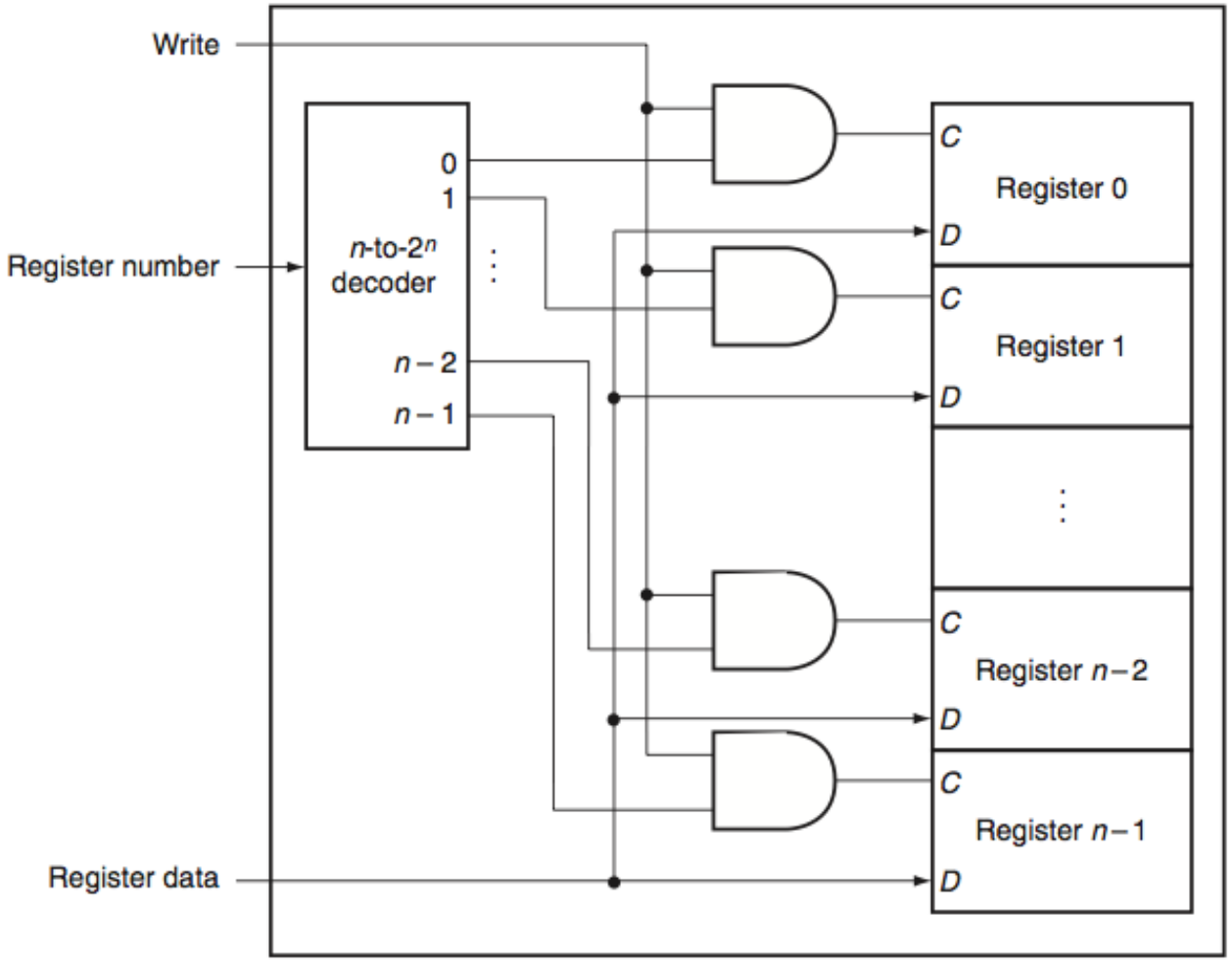



```
00100001001010010000000000000101
```

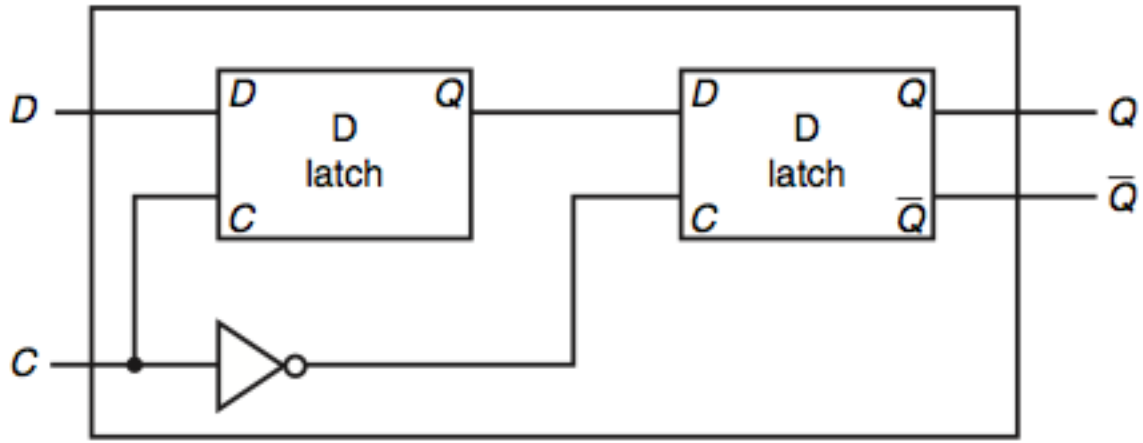
Actually The Datapath



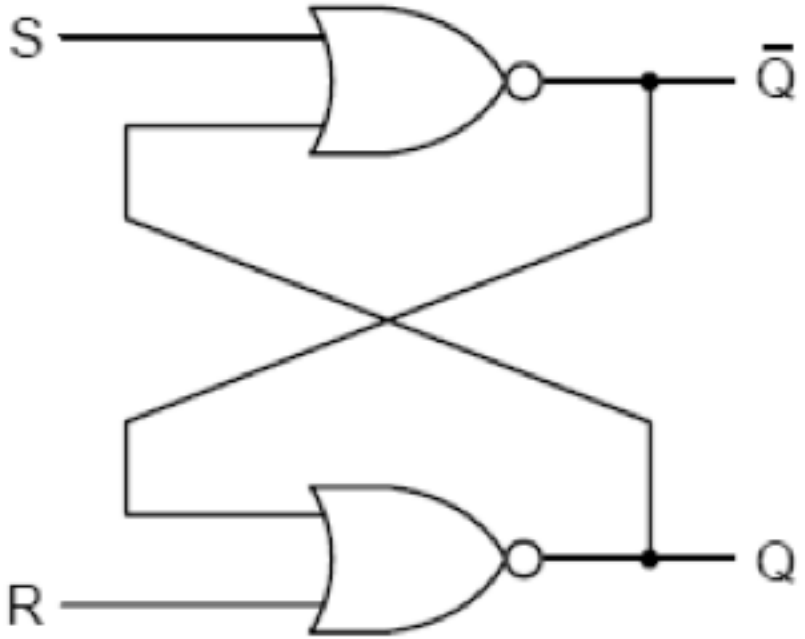
Actually Registers



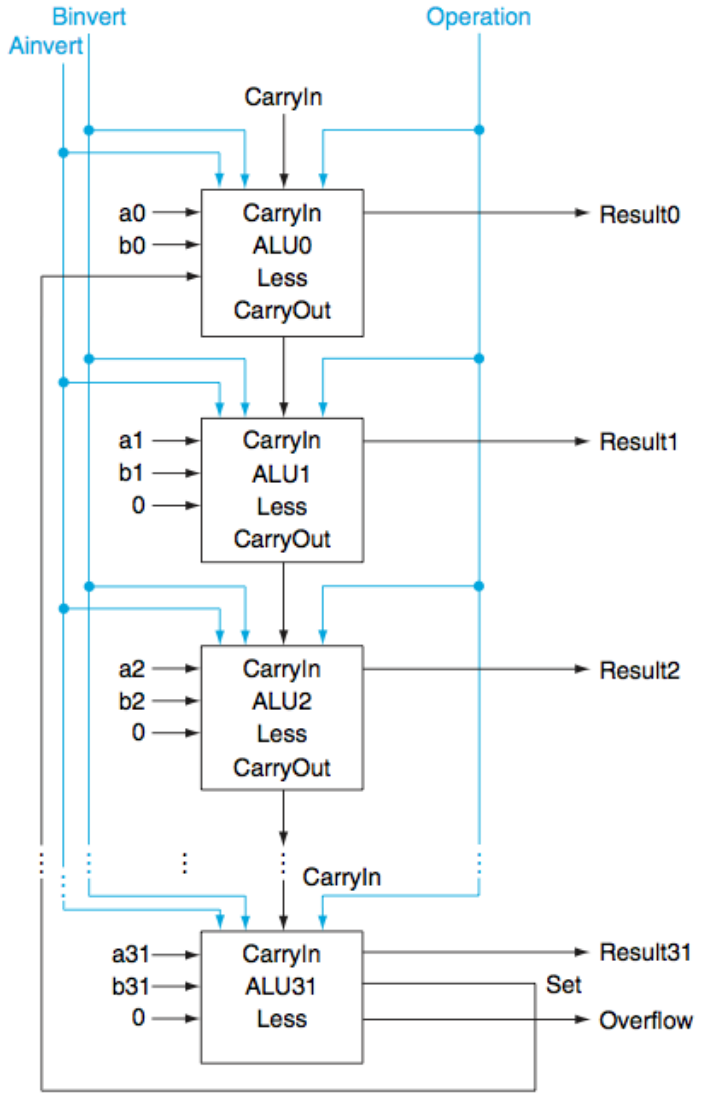
Actually Flip-flops



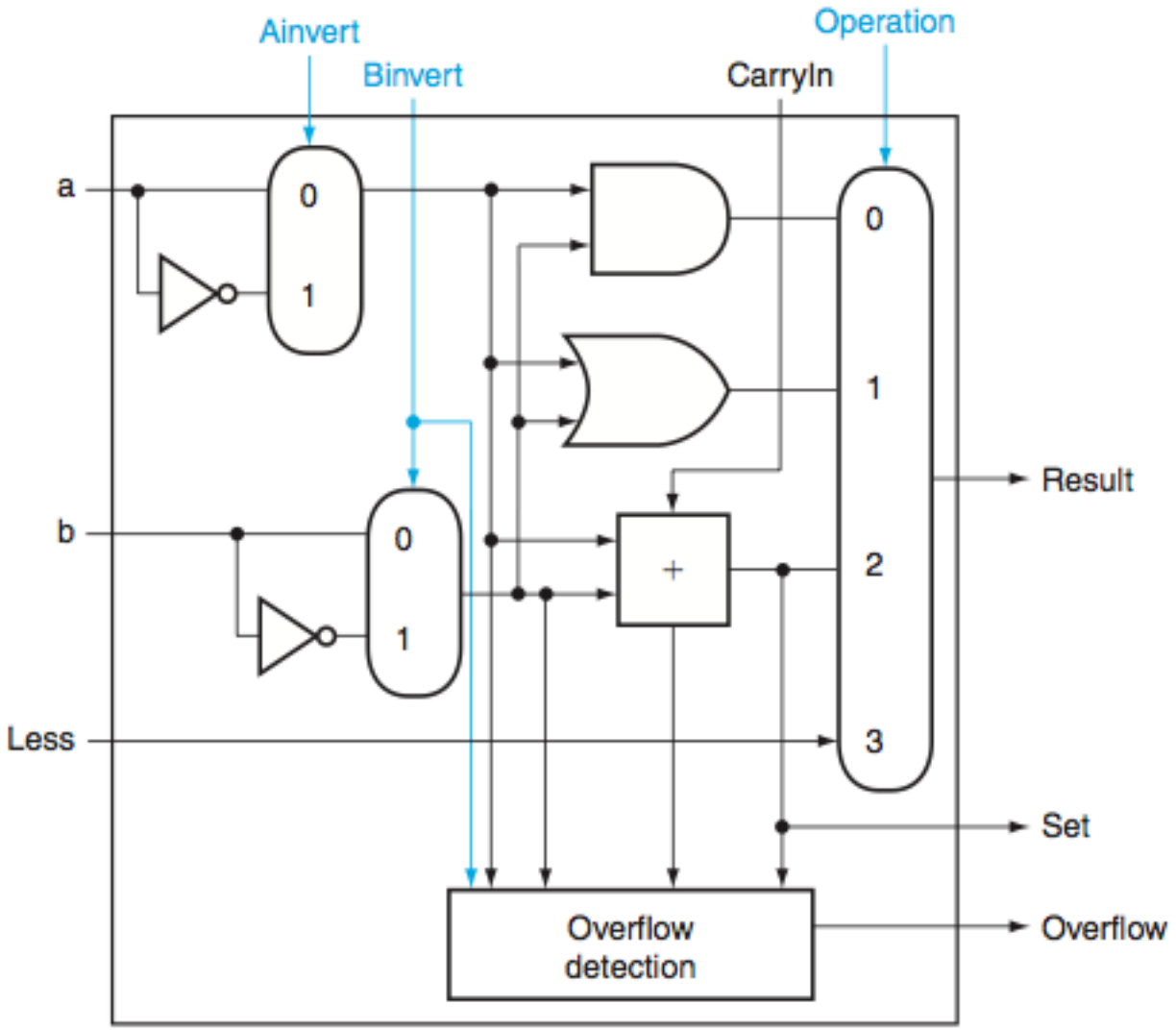
Actually Latches



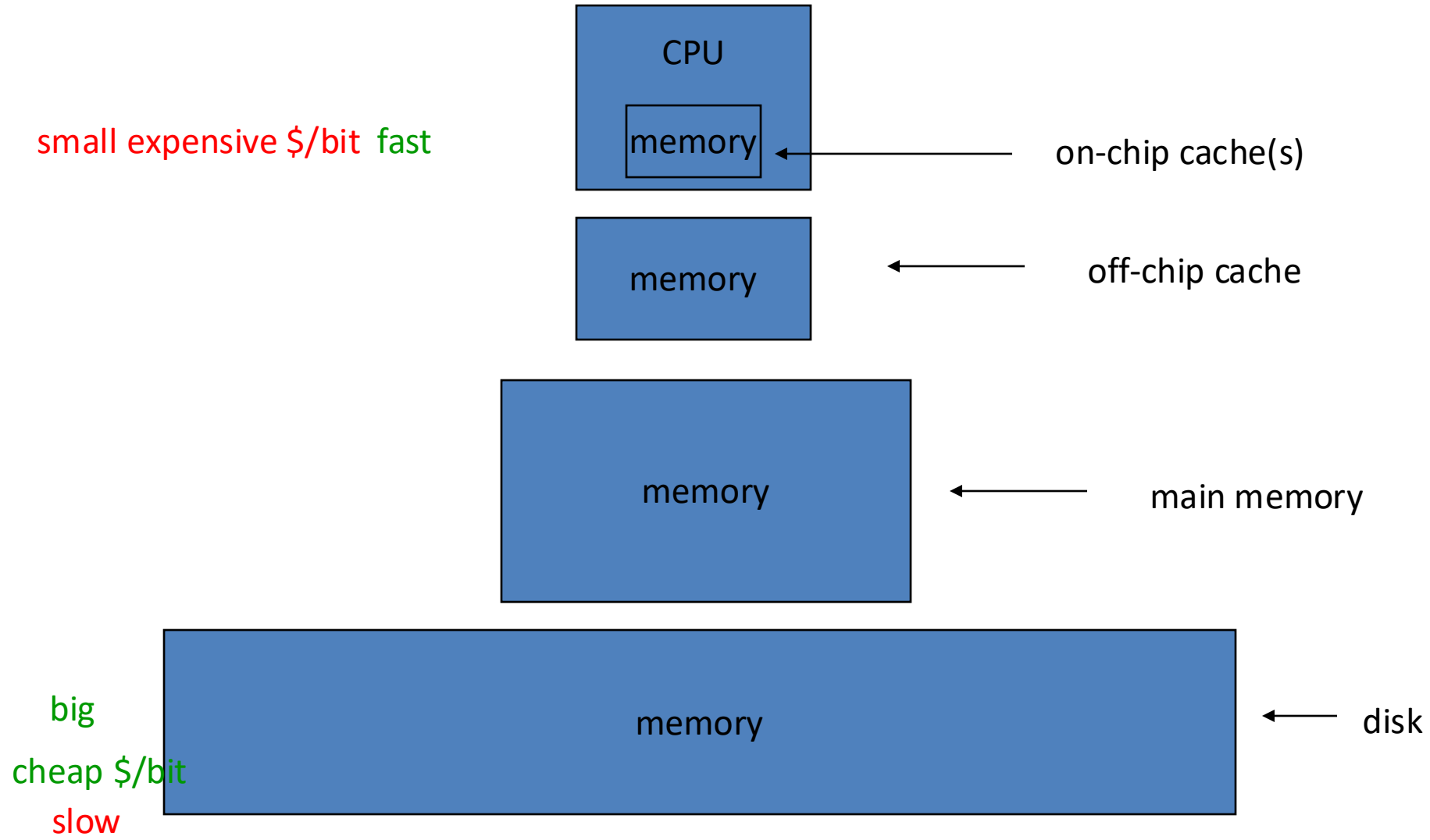
Actually the ALU



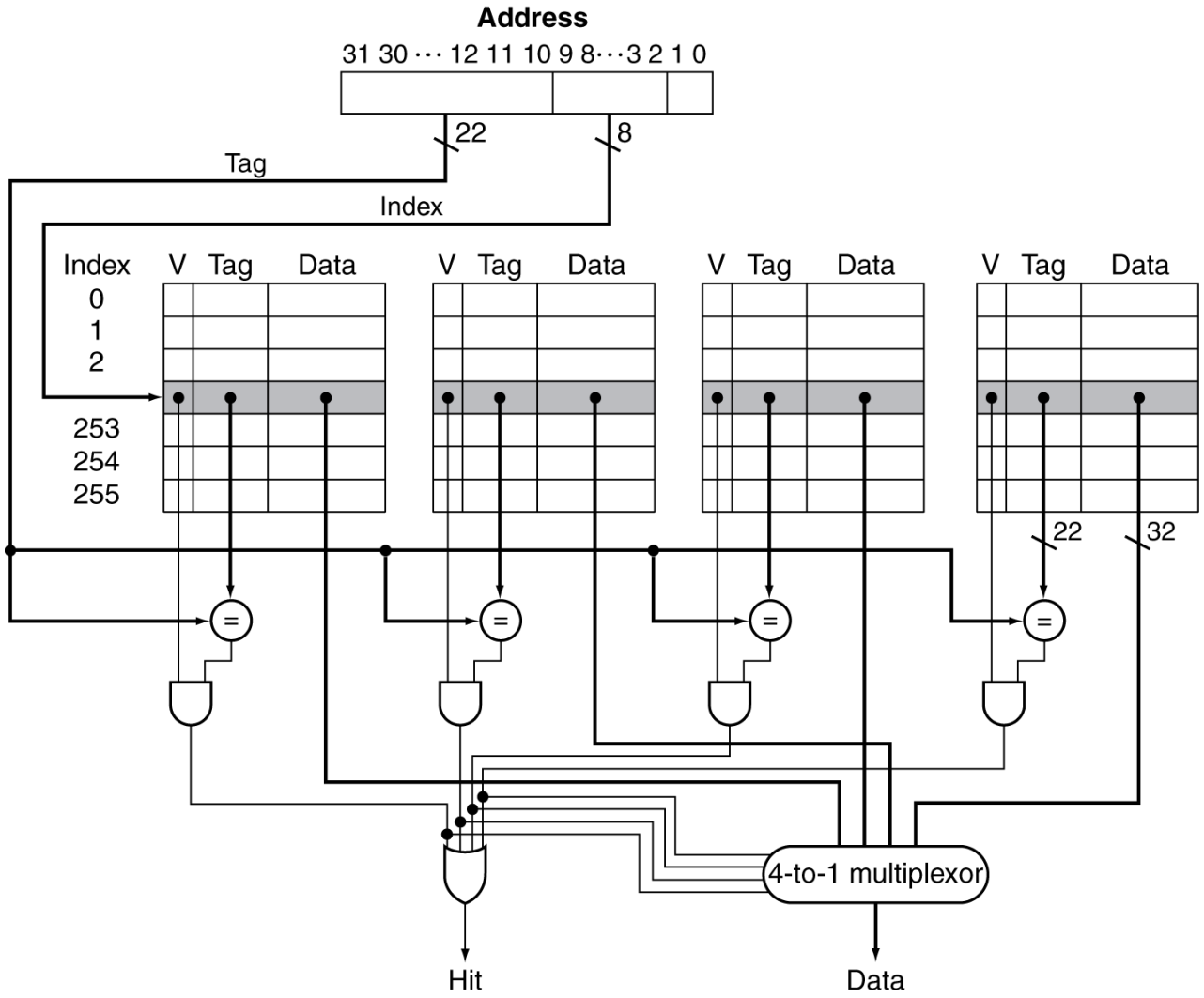
Actually the ALU



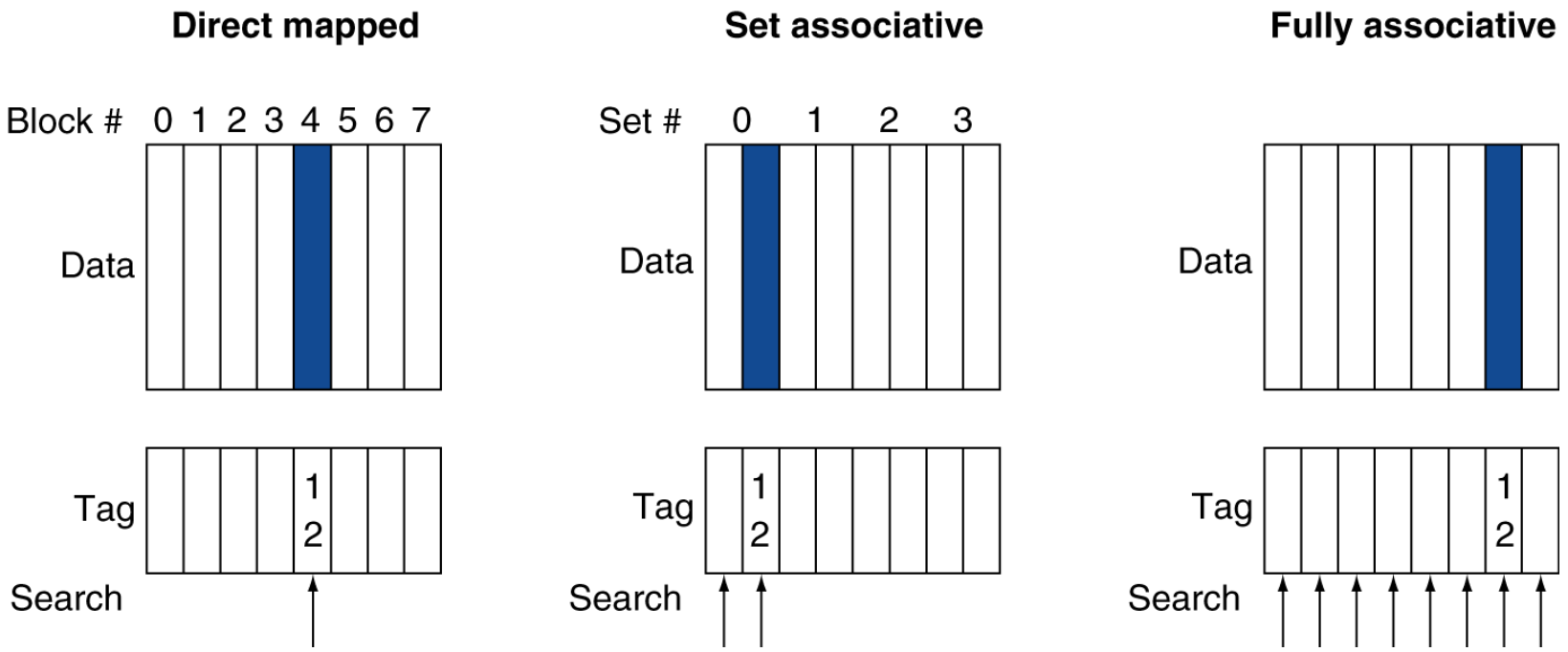
Actually Memory



Actually Caches



Actually LOTS of Caches



But wait, what about?

- Negative Numbers
- Floating Point
- All that other stuff . . .

Computers are Complicated

- But now, you know how they work. Kinda.

- I appreciate all the work you've done for this class.
- Have a great summer!
- …and fill out course evals!

Questions?

Reading