Memory & Caches II

CSE 351 Autumn 2023

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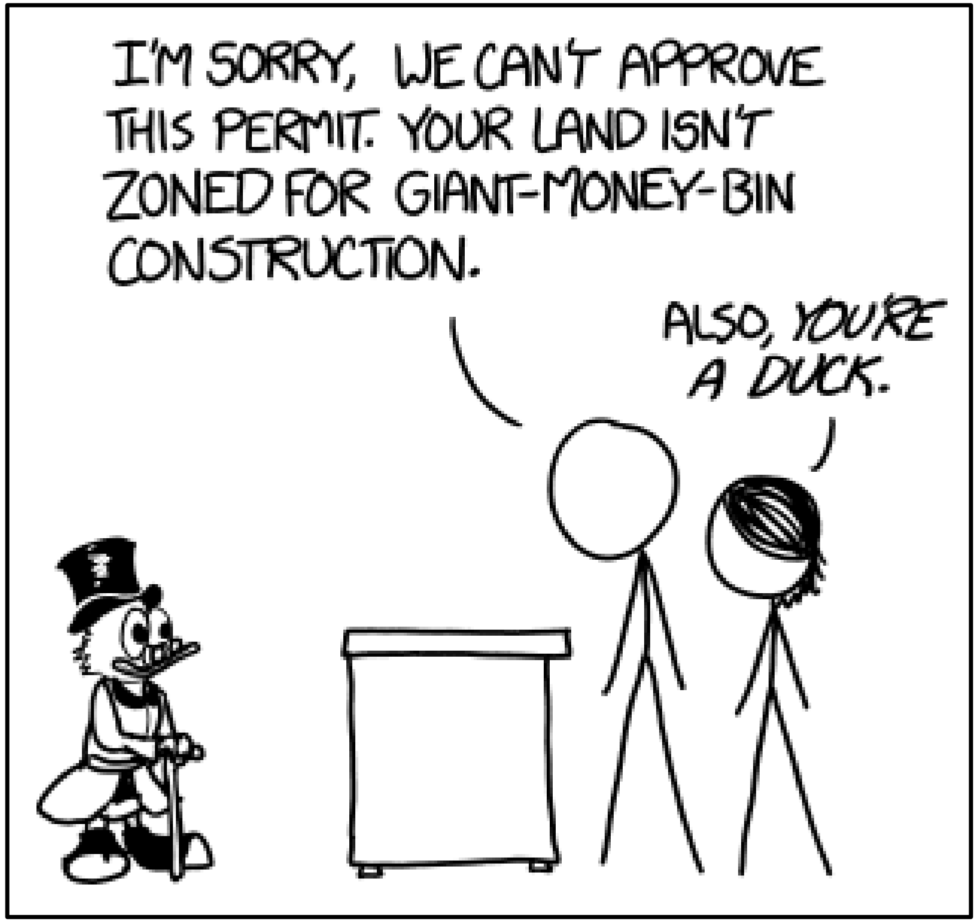


https://what-if.xkcd.com/111/

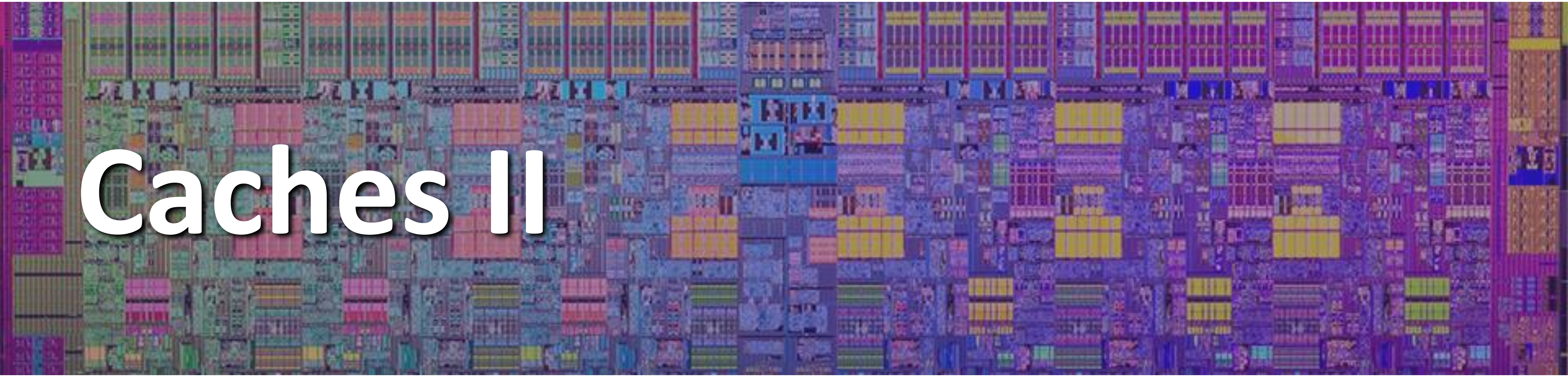
Relevant Course Information

- Mid-quarter Survey due Wednesday (11/8)
- hw16 due Wednesday (11/8)
- hw17 due *next* Wednesday (11/15)
  - Don’t wait too long, this is a BIG hw (includes this lecture)
- Lab 3 due Friday (11/10)
  - Veteran’s Day: no lecture, but some support hours (see Ed)
- Midterm grades will be released when we can
  - Regrade requests will be available afterward

New Lecture Format

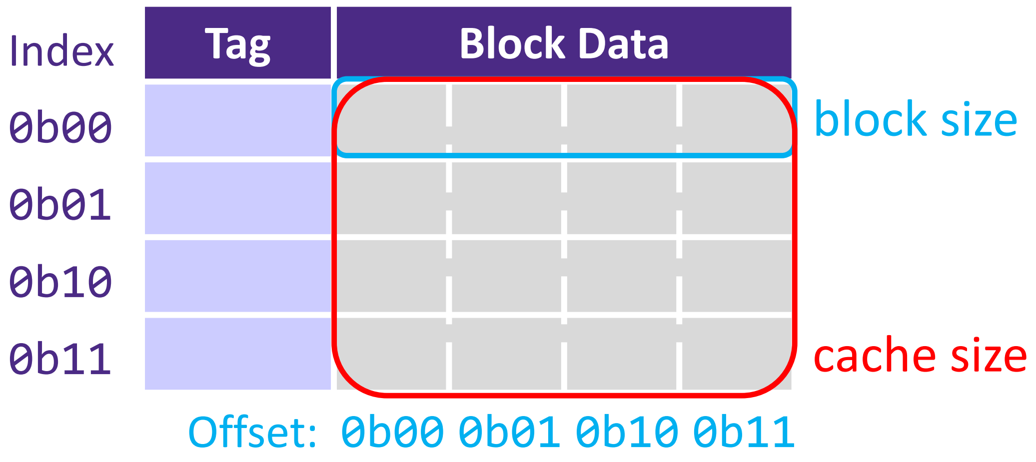
- Lesson Summary will be a little more detailed than before [5–7 min]
- Context section will “float” depending on content:
  - May be skipped for some lectures
  - May come after summary (as before) or may be held until end of lecture
  - Random call for share-out by section of the room for discussion questions
- Practice section will go problem-by-problem
  - Justin will introduce the problem
  - Then, limited group work time [3–8 min, depending on difficulty]
  - Random call for share-out by section of the room
    - Do not need to have finished the problem, just share out what work you did
- *The quicker we get responses, the quicker we can move on*

Caches II



Lesson Summary (1/2)

- Cache parameters define the cache geometry:
  - **Block size** is number of bytes per block
  - **Cache size** is number of bytes (or blocks) of data the cache can hold
- Finding a byte in the cache:
  - **Offset** refer to which byte in block
  - **Index** refers to which block in cache
- Example:
  - K = 4 B, C = 16 B = 4 blocks



Lesson Summary (2/2)

- **Direct-mapped cache:** each block in cache is assigned a unique index
  - Uses hash function of (block number) mod (# of cache indices)
    - Deterministic placement of each block, with many blocks mapping into the same index
    - Tag bits stored in cache and used to distinguish between blocks that map to same index

- Accessing the cache:
  (TIO address breakdown)

$\boldsymbol{m}$-bit address: $\underbrace{\boxed{\text{Tag } (\boldsymbol{t})} \boxed{\text{Index } (\boldsymbol{s})}}_{\text{Block Number}} \boxed{\text{Offset } (\boldsymbol{k})}$

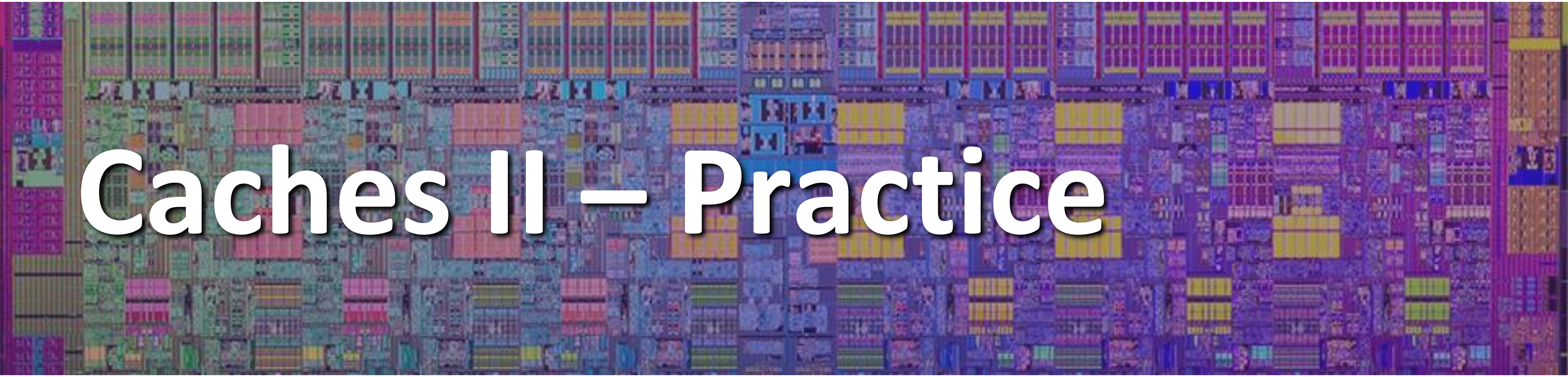
1) **Index** field tells you where to look in cache (width $s = \log_2 S$)
2) **Tag** field lets you check that data is the block you want (width $t = m - s - k$)
3) **Offset** field selects specified start byte within block (width $k = \log_2 K$)

Lesson Q&A

- Terminology:
  - Cache parameters: block size (K), cache size (C), number of indices (S)
  - Address fields: tag (t bits wide), index (s bits wide), block offset (k bits wide)
  - Cache organization: direct-mapped cache

- Learning Objectives:
  - Determine how memory addresses and data interact with the cache (*i.e.*, cache lookups, data movement).
  - Analyze how changes to cache parameters [and policies] affect performance metrics such as AMAT.

- What lingering questions do you have from the lesson?



Caches II – Practice

Practice Questions (1/2)

- We have a direct-mapped cache with the following parameters:
  - Block size of 8 bytes
  - Cache size of 4 KiB

- How many blocks can the cache hold?
- How many bits wide is the block offset field?
- Which of the following addresses would fall under block number 3?

A. 0x3 B. 0x1F C. 0x30 D. 0x38

Practice Questions (2/2)

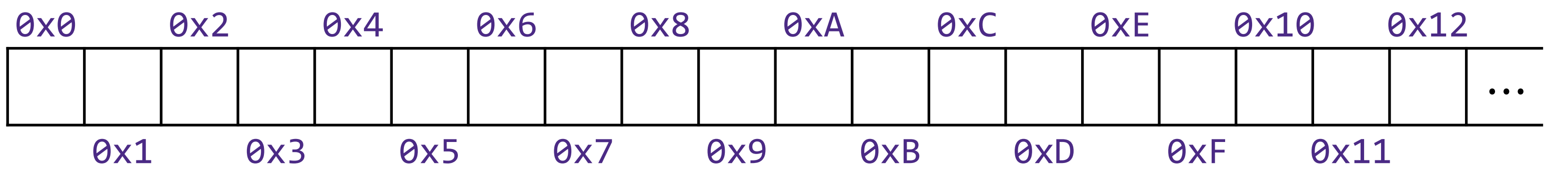
- Based on the following behavior, which of the following block sizes is NOT possible for our cache?
  - Cache starts *empty*, also known as a *cold cache*
  - Access (addr: hit/miss) stream:
    - (`0xE`: miss), (`0xF`: hit), (`0x10`: miss)

A. 4 bytes

B. 8 bytes

C. 16 bytes

D. 32 bytes



Homework Question Setup

- Consider the following function, which computes the dot product of two vectors:

```
float dotprod(float x[8], float y[8]) {
   float sum = 0.0;
   for (int i = 0; i < 8; i++)
      sum += x[i] * y[i];
   return sum;
}
```

  - &x=0x0, &y=0x20. sizeof(float)=4. Direct-mapped $ with indices, each 16 B.
  - **What does the cache look like?**

Homework Question Setup

- Consider the following function, which computes the dot product of two vectors:

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float dotprod(float x[8], float y[8]) {
   float sum = 0.0;
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      sum += x[i] * y[i];
   return sum;
}
```

  - `&x=0x0`, `&y=0x20`. `sizeof(float)=4`. Direct-mapped $ with indices, each 16 B.
  - **List out the first 8 memory accesses in terms of x and y, then translate those to addresses:**

Group Work Time

- During this time, you are encouraged to work on the following:
  1) If desired, continue your discussion
  2) Work on the homework problems
  3) Work on the current lab

- Resources:
  - You can revisit the lesson material
  - Work together in groups and help each other out
  - Course staff will circle around to provide support