Data III & Integers I

CSE 351 Autumn 2023

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http://xkcd.com/257/

Relevant Course Information

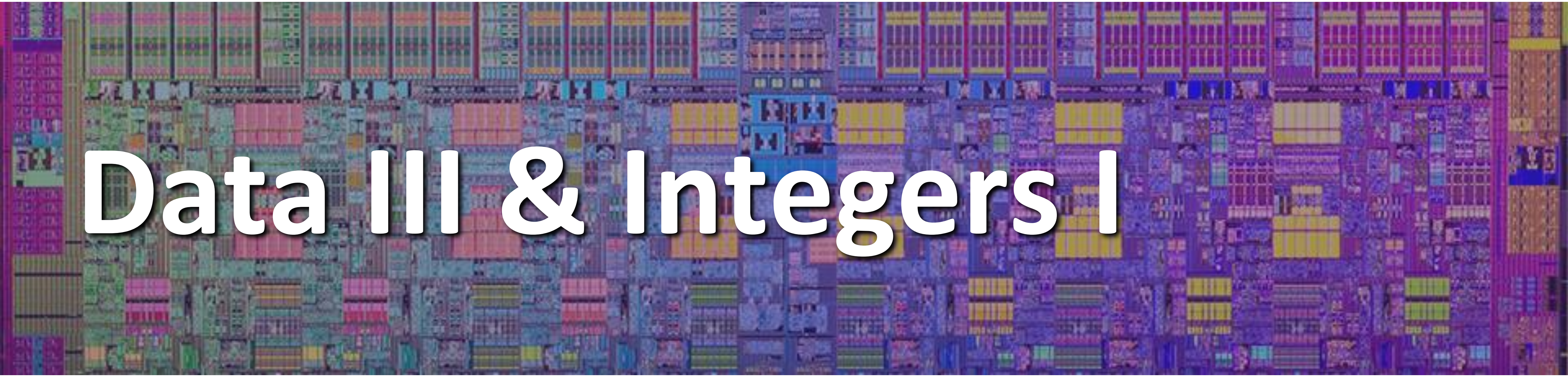
- hw3 due Friday, hw4 due Monday

- Lab 1a released
  - Some later functions require *bit shifting*, covered in Lesson 5
  - Workflow:
    1) Edit `pointer.c`
    2) Run the Makefile (`make clean` followed by `make`) and check for compiler errors & warnings
    3) Run ptest (`./ptest`) and check for correct behavior
    4) Run rule/syntax checker (`python3 dlc.py`) and check output
  - Due Monday 10/9, will overlap a bit with Lab 1b
    - We grade just your *last* submission
    - Don’t wait until the last minute to submit – need to check autograder output

Lab Synthesis Questions

- All subsequent labs (after Lab 0) have a “synthesis question” portion
  - Can be found on the lab specs and are intended to be done *after* you finish the lab
  - You will type up your responses in a `.txt` file for submission on Gradescope
  - These will be graded “by hand” (read by TAs)

- Intended to check your understand of what you should have learned from the lab
  - Also great practice for short answer questions on the exams



Data III & Integers I

Lesson Summary (1/2)

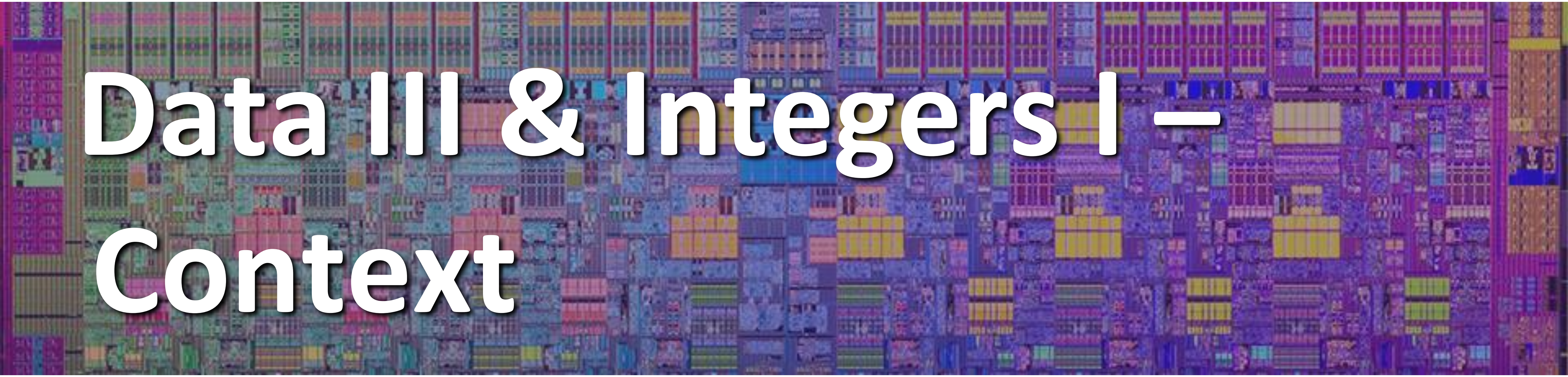
- Bit-level operators allow for fine-grained manipulations of data
  - Bitwise AND (`&`), OR (`|`), and NOT (`~`) different than logical AND (`&&`), OR (`||`), and NOT (`!`)
  - Especially useful with bitmasks – chosen bit vectors used with &, |, or ^
- Choice of *encoding scheme* is important
  - Tradeoffs based on size requirements and desired operations
- Integers represented using unsigned and two's complement representations
  - Limited by fixed bit width, satisfy desirable arithmetic properties

Lesson Summary (2/2)

- Terminology:
  - Bitwise operators (&, |, ^, ~), Logical operators (&&, ||, !)
  - Short-circuit evaluation
  - Unsigned integers, Signed integers (Two's Complement)

- Learning Objectives:
  - Compute the effects of bit shifting, bitwise, logical, and arithmetic operations on integers.
  - Analyze the benefits and drawbacks of different integer representations (Unsigned, Sign and Magnitude, Two's Complement) and custom encoding schemes.

- What lingering questions do you have from the lesson?



Data III & Integers I – Context

Integer Hardware

- In practice, all modern system use **unsigned** and **two's complement** encoding schemes for integers
  - Sign and magnitude for integers is a historical artifact, but useful context for design decision and for floating point (next lesson)
  - Much of the same hardware can be used for both encoding schemes (*e.g.*, addition, subtraction)

- Fun fact: Java was designed to only support <u>signed</u> data types
  - *Assumed easier for beginners to understand* than having unsigned as well (*i.e.*, eliminate potential sources of error)
  - Unsigned operation support provided with Unsigned Integer API (starting with Java SE 8 in 2014)

Discussion Question

- Discuss the following question(s) in groups of 3-4 students
  - I will call on a few groups afterwards so please be prepared to share out
  - Be respectful of others' opinions and experiences

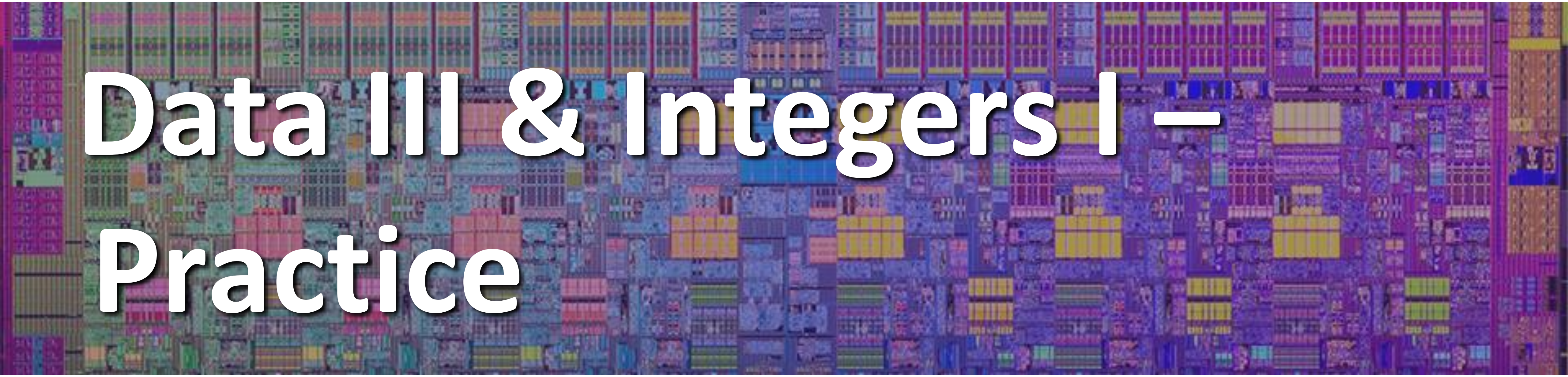
- Thinking about the (implicit and explicit) design decisions for Two's Complement, what are some of the *advantages* and *disadvantages* of choosing to:
  - Represent consecutive (*i.e.*, no gaps) integers

    example, if only representing even integers, what should happen when we compute 6/2 ?
  - Represent the same number of positives and negatives

    the bias should make sense in the context of our application

    arithmetic might get weird again...
  - Positive number encodings match unsigned

    no need to convert anything when changing interpretations



Data III & Integers I – Practice

Group Work Time

- During this time, you are encouraged to work on the following:
  1) If desired, continue your discussion
  2) Work on the lesson problems (solutions at the end of class)
  3) Work on the homework problems

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

Practice Questions (1/2)

- Compute the result of the following expressions for
  `char c = 0x81;` // 0b 1000 0001
  - `c ^ c` = $\boxed{0x00}$
    1000 0001
    1000 0001
    0000 0000
  - `~c & 0xA9` = $\boxed{0x28}$
    0b 0111 1110
    0b 1010 1001
    0010 1000
  - "true" `c || 0x80` "true" = "true" $\boxed{0x01}$
  - `!(!c)` = "true" $\boxed{0x01}$
    "false" 0x0
- Compute the value of `signed char sc = 0xF0;` (Two's Complement)

  = 0b 1111 0000

  $= -2^7+2^6+2^5+2^4$

  $\boxed{= -16}$

  $-sc = \sim sc + 1 =$ 0b 0000 1111
  \+ 1
  0b 0001 0000 = +16

  $\boxed{sc = -16}$

Practice Questions (2/2)

MSB

- Take the 4-bit number encoding **`x = 0b1011`**
- Which of the following numbers is NOT a valid interpretation of `x` using any of the number representation schemes discussed today?
  - Unsigned, Sign and Magnitude, Two's Complement

A. -4

$\boxed{\textbf{B.}\ \ -5}$

~~**C.** 11~~

~~**D.** -3~~

~~**E.** We're lost…~~

unsigned: $8+2+1=11$

sign + mag: $1011 \rightarrow -(2+1)=-3$

two's: $-8+2+1=-5$

$-x = 0b\ 0100+1 = 5 \rightarrow x=-5$