EE/CS120A: Logic Design

Prof. Usagi (a.k.a. Hung-Wei Tseng)

Greetings

What's your name?

What's your feeling about stay-at-home?

Zoom Lecture Experience

Lecture	Poll	Discussion/Answer/ Questions	Lecture	Poll	D
Listen/Learn/Think/Mute	Think/Mute/ Answer	Raise Hands/ Unmute/Speak	Listen/Learn/Think/Mute	Think/Mute/ Answer	

Logic Design?

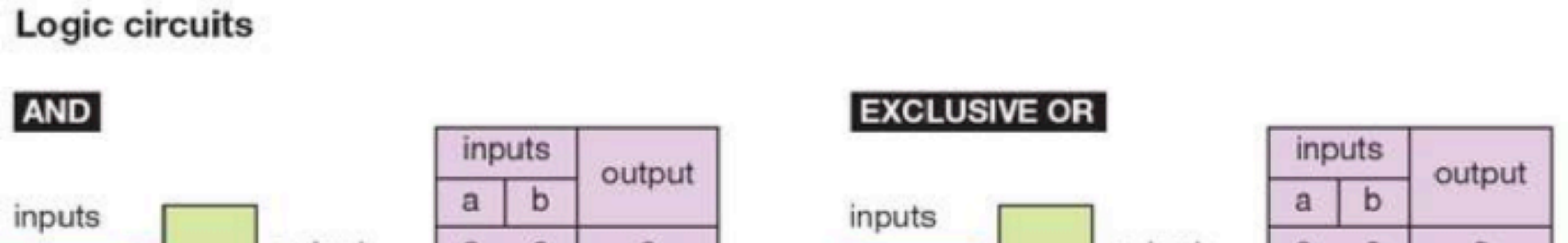
Logic design

COMPUTER TECHNOLOGY

https://www.britannica.com/technology/logic-design

WRITTEN BY: The Editors of Encyclopaedia Britannica
See Article History

Logic design, Basic organization of the circuitry of a digital computer. All digital computers are based on a two-valued logic system—1/0, on/off, yes/no (*see* binary code). Computers perform calculations using components called logic gates, which are made up of integrated circuits that receive an input signal, process it, and change it into an output signal. The components of the gates pass or block a clock pulse as it travels through them, and the output bits of the gates control other gates or output the result. There are three basic kinds of logic gates, called “and,” “or,” and “not.” By connecting logic gates together, a device can be constructed that can perform basic arithmetic functions.



“Digital” Computers

Computer

GAMES | BROWSE THESAURUS | WORD OF THE DAY | WORDS AT

Merriam-Webster SINCE 1828

computer

DICTIONARY THESAURUS

computer noun, often attributive

Save Word

com·put·er | \ kəm-ˈpyü-tər \

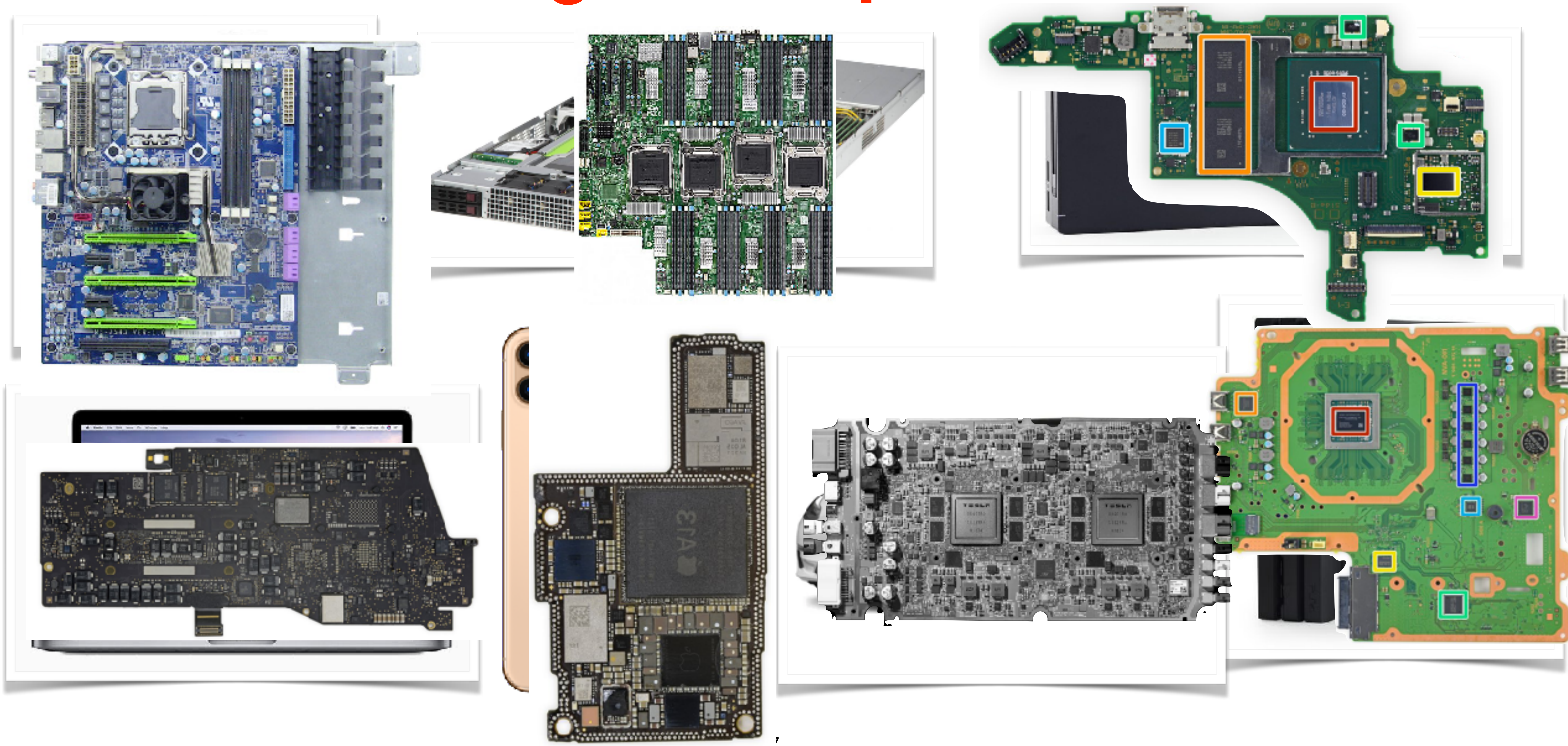
Definition of *computer*

: one that computes

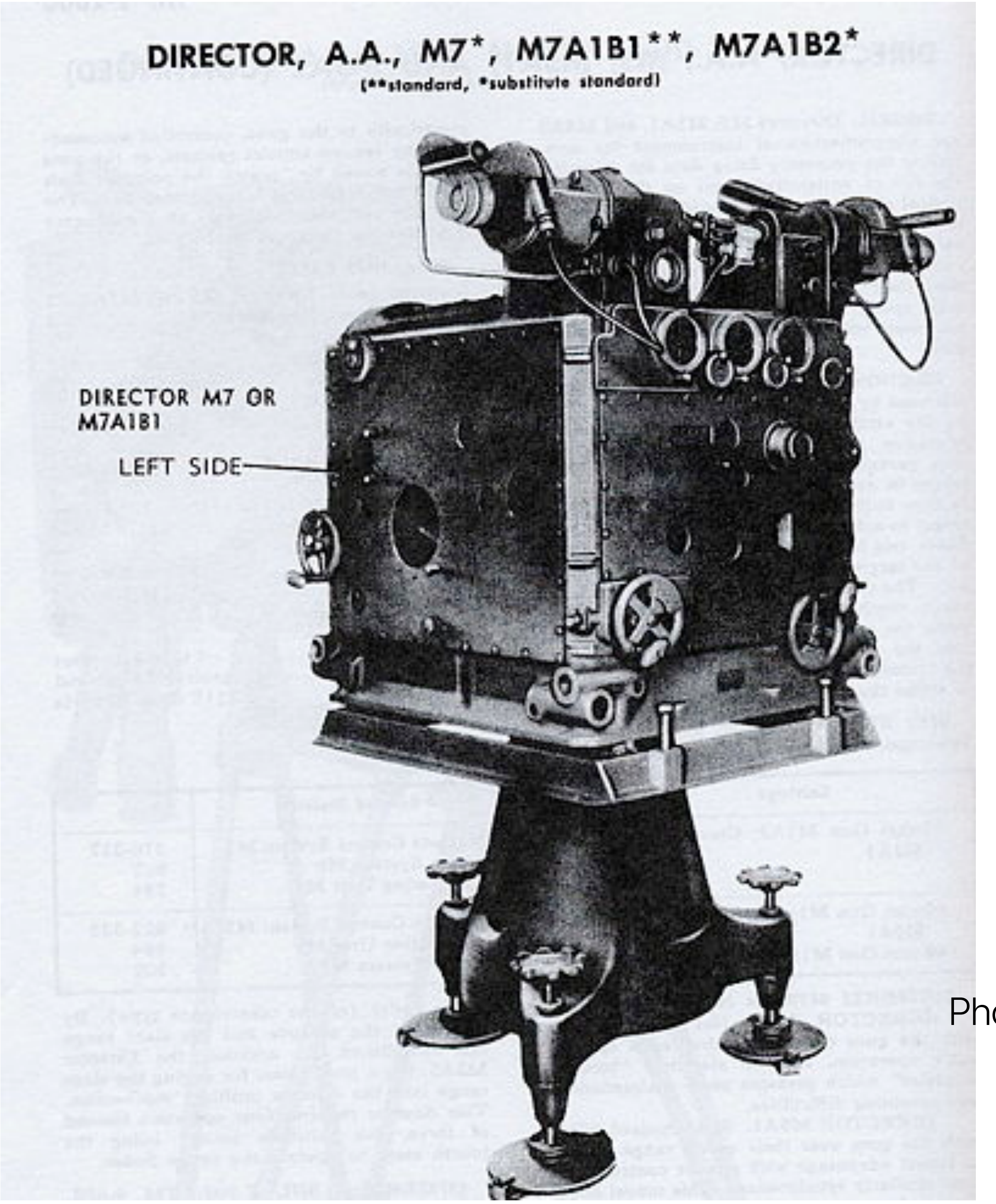
specifically : a programmable usually electronic device that can store, retrieve, and process data

// using a *computer* to design 3-D models

Digital Computers



Computers that are not "digital"



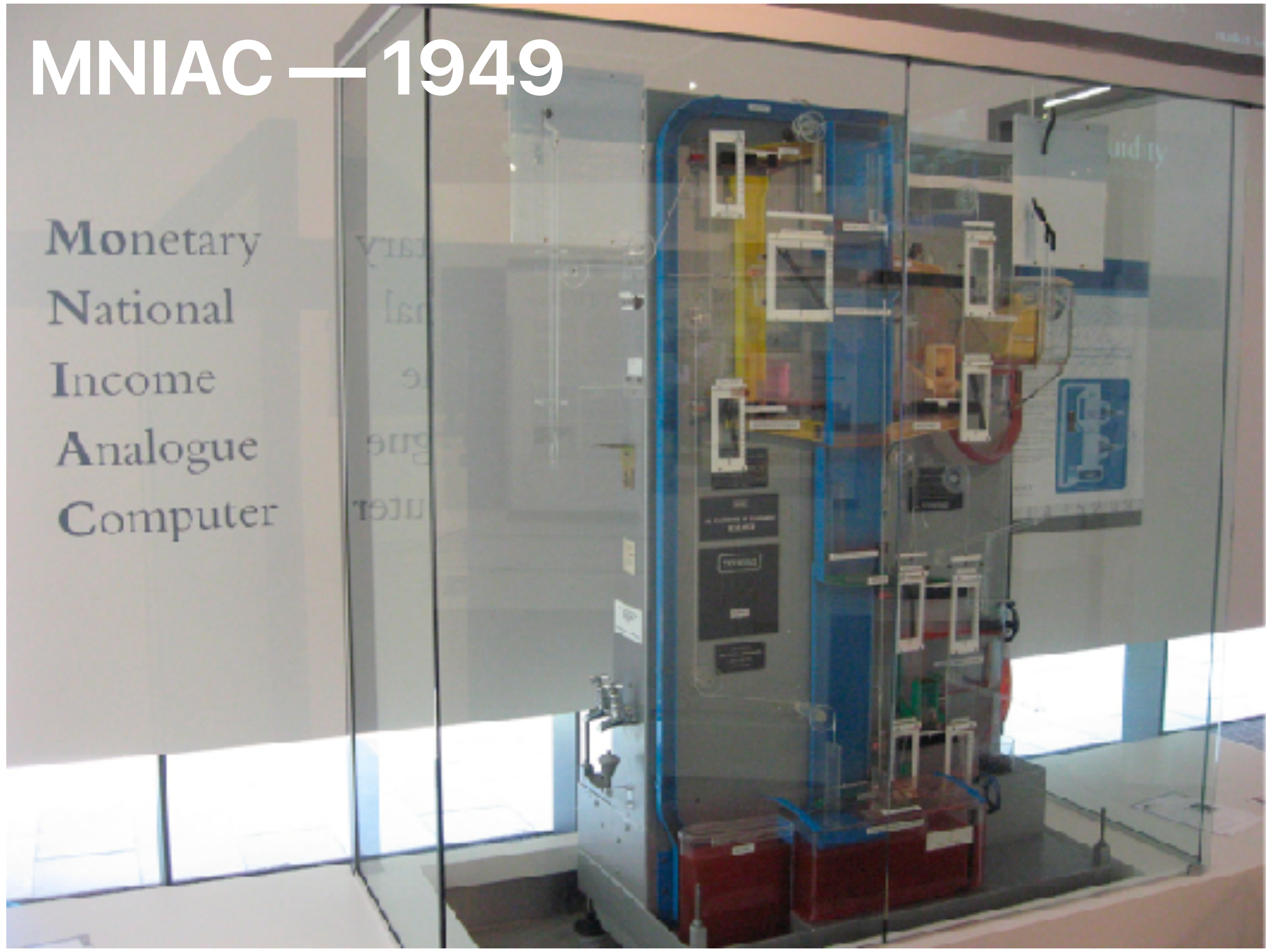


Photo Credit By Kaihsu Tai, https://commons.wikimedia.org/w/index.php?curid=3956307

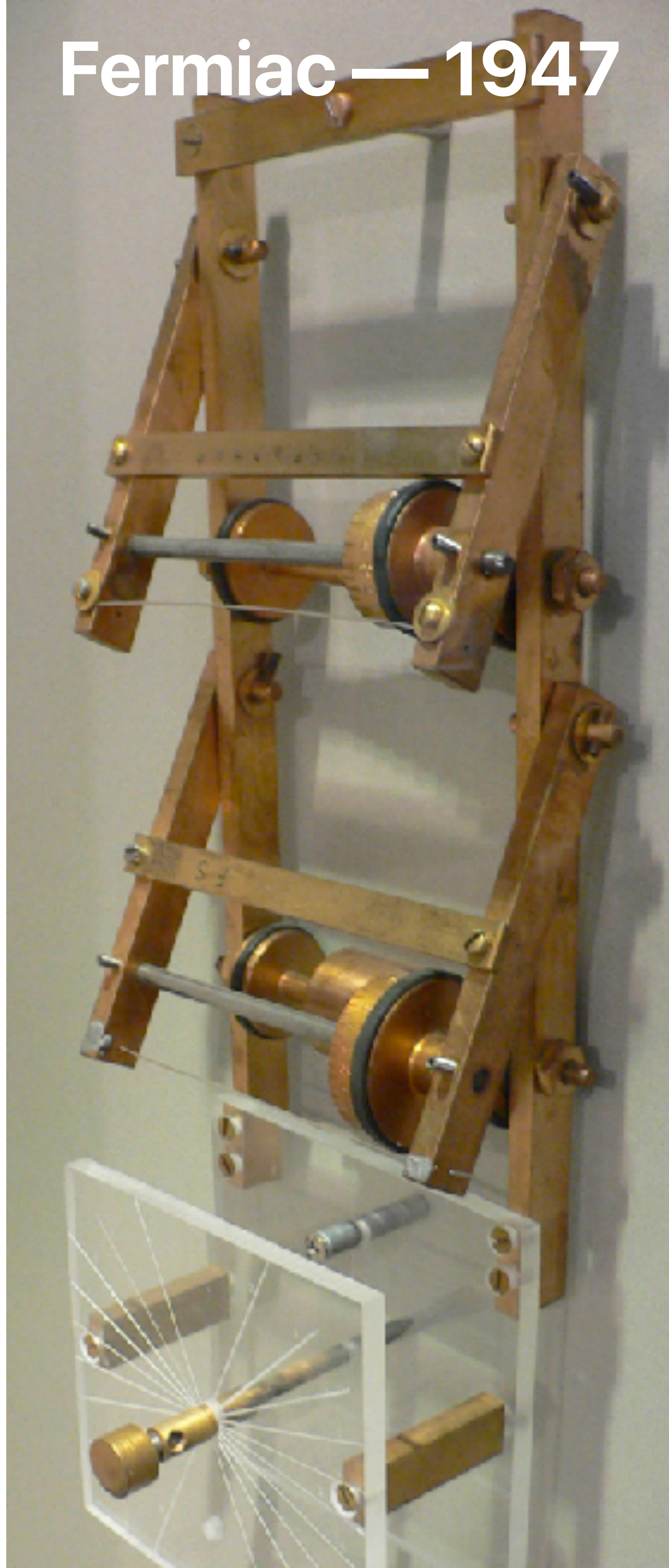


Photo Credit By Mark Pellegrini, CC BY-SA 1.0, https://commons.wikimedia.org/w/index.php?curid=7878402

Poll close in 1:30

Why are digital computers more popular now?

- Please identify how many of the following statements explains why digital computers are now more popular than analog computers.
  ① The cost of building systems with the same functionality is lower by using digital computers.
  ② Digital computers can express more values than analog computers.
  ③ Digital signals are less fragile to noise and defective/low-quality components.
  ④ Digital data are easier to store.
  A. 0
  B. 1
  C. 2
  D. 3
  E. 4

Moore's Law[1]

Present and future

By integrated electronics, I mean … technologies which are referred to … tronics today as well as any additi… result in electronics functions suppli… as irreducible units. These technolo… i… to miniaturize electronics equipment … creasingly complex electronic functi… space with minimum weight. Sever… evolved, including microassembly … individual components, thin-film s… semiconductor integrated circuits.

ICs are increasingly p…

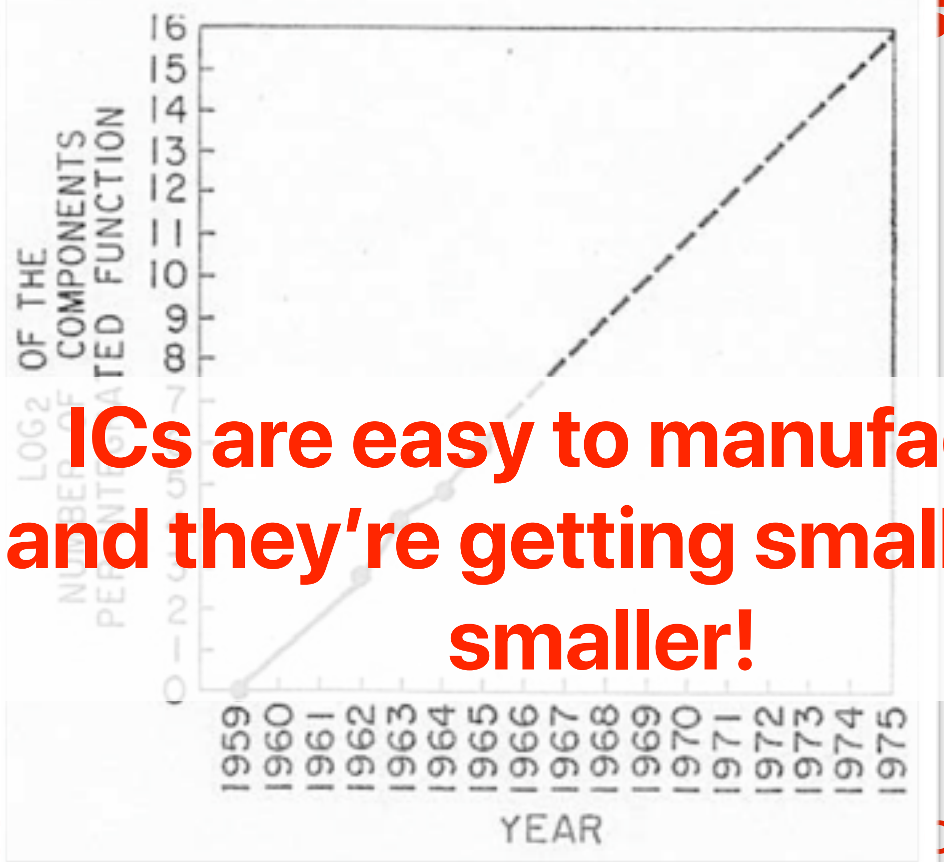
The establishment

Integrated electronics is established … for new … and … vable … llo, fo… he reli… that … ilure as the …

…tablish…

Increasing the yield

There is no fundamental obstacle to achieving device yields of 100%. At present, packaging costs so far exceed the cost of the semiconductor structure itself that there is no incentive to improve yields, but they can be raised as high as is economically justified. No barrier exists comparable to the thermodynamic equilibrium considerations



ICs are easy to manufacture and they're getting smaller and smaller!

Reliability coun…

In almost e… demonstrated h… level of production—low compared to that of discrete components—it offers reduced systems cost, and in many systems improved performance has been realized.

ICs are more reliable

Linear circuitry

Integration will not change linear systems as radically as digital systems. Still, a considerable degree of integration will be achieved with linear circuits. The lack of large-value capacitors and … to integrated electronics in the linear area.

ICs are widely applicable

Heat problem

Will it be possible to remove the heat generated by tens of thousands of components in a single silicon chip?

Heat is a solvable issue

Moore's … impo… historic

Two-mil squares

With the dimensional tolerances already being employed in integrated circuits, isolated high-performance transistors can be built on centers two thousandths of an inch apart. Such a two-mil square can also contain several kilohms of resistance o…

ICs are small

Day of reckoning

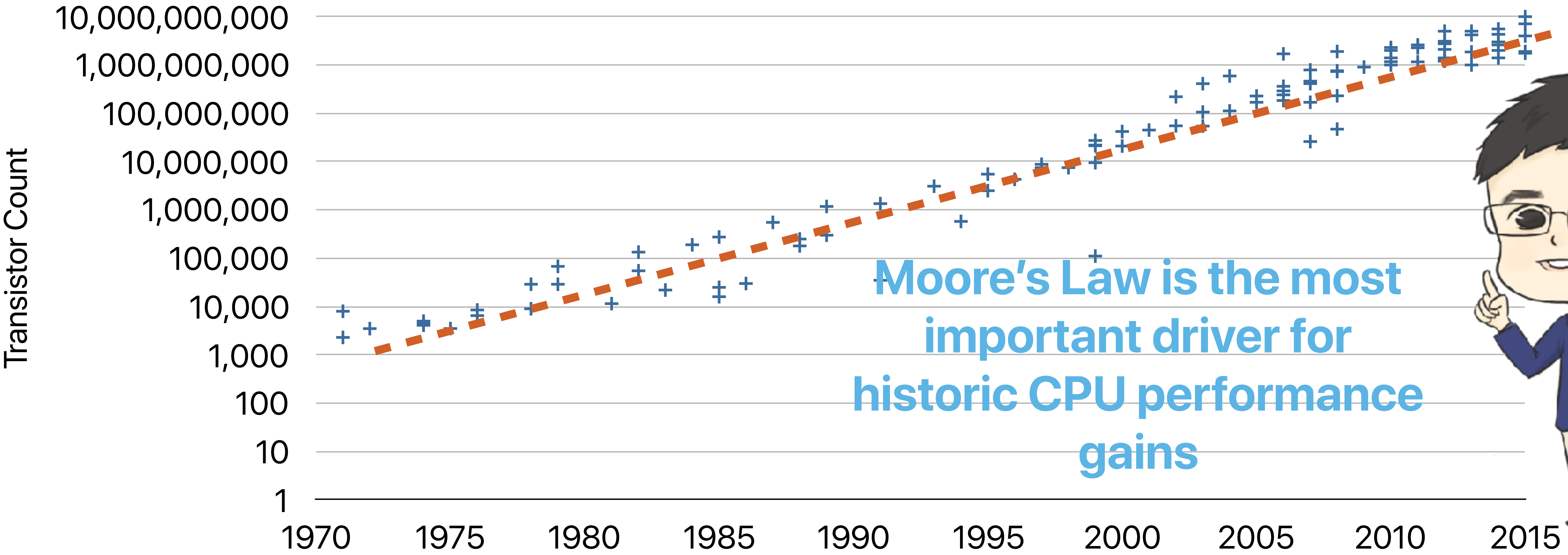
Clearly, we will be able to build such component-crammed equipment. Next, we ask under what circumstances we should do it. The total cost of making a particular system function must be minimized. To do so, we could amortize the engineering over several identical items, or evolve flexible techniques for the engineering of large functions so that no disproportionate expense need be borne by a particular array. Perhaps newly devised design automation procedures could translate from … any special engineering.

Designing ICs can be easy

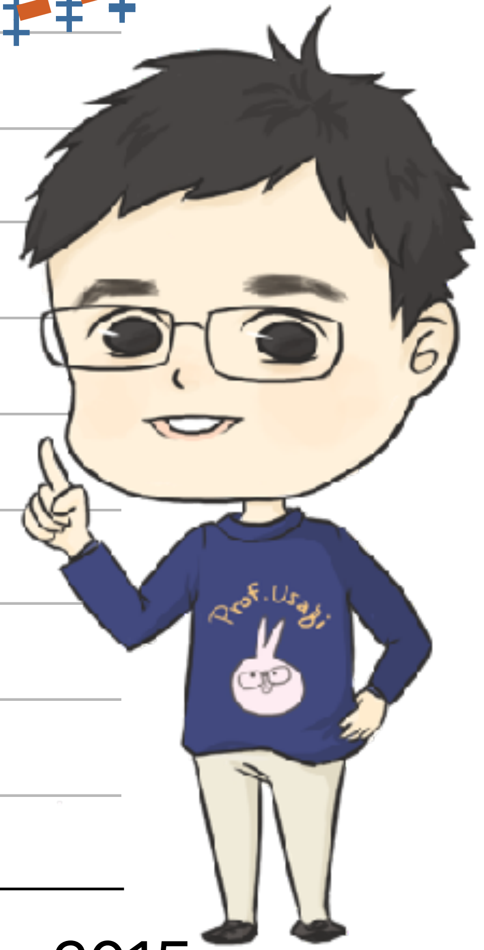
(1) Mo… …mponents onto integrated circuits', Electronics 38 (8) .

Moore's Law[1]

- The number of transistors we can build in a fixed area of silicon doubles every 12 ~ 24 months.



Moore's Law is the most important driver for historic CPU performance gains



(1) Moore, G. E. (1965), 'Cramming more components onto integrated circuits', Electronics 38 (8) .

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  - C. 2
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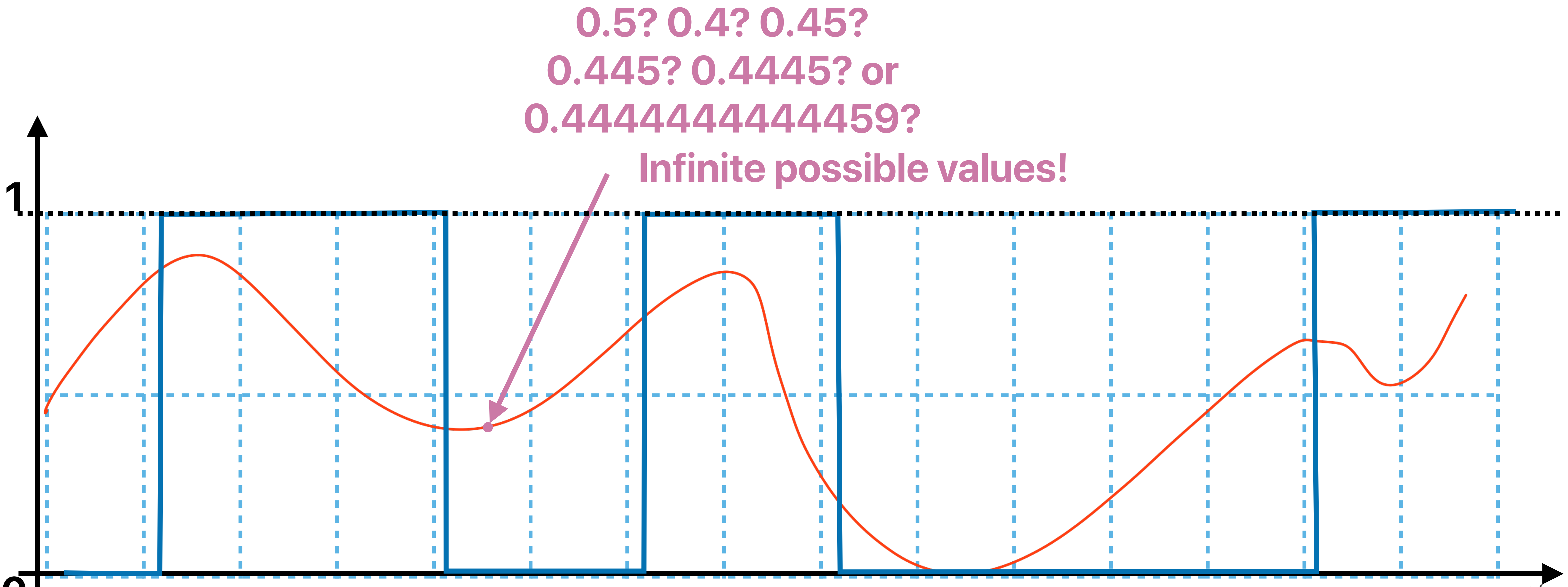
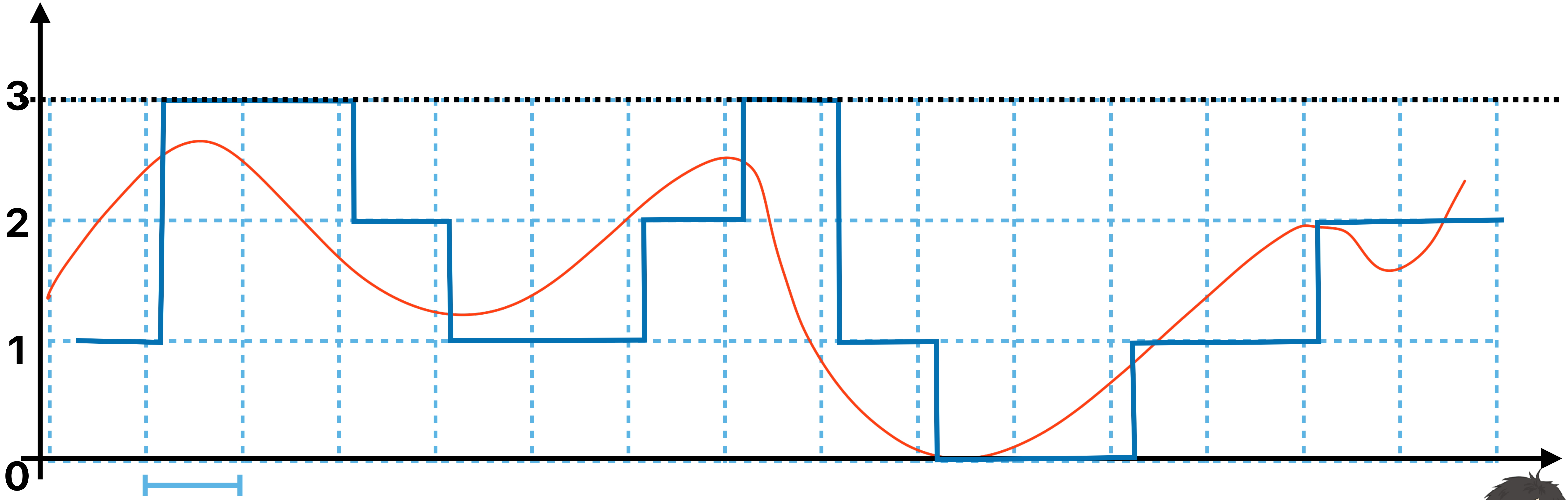
  - E. 4

Analog v.s. digital signals



Analog v.s. digital signals



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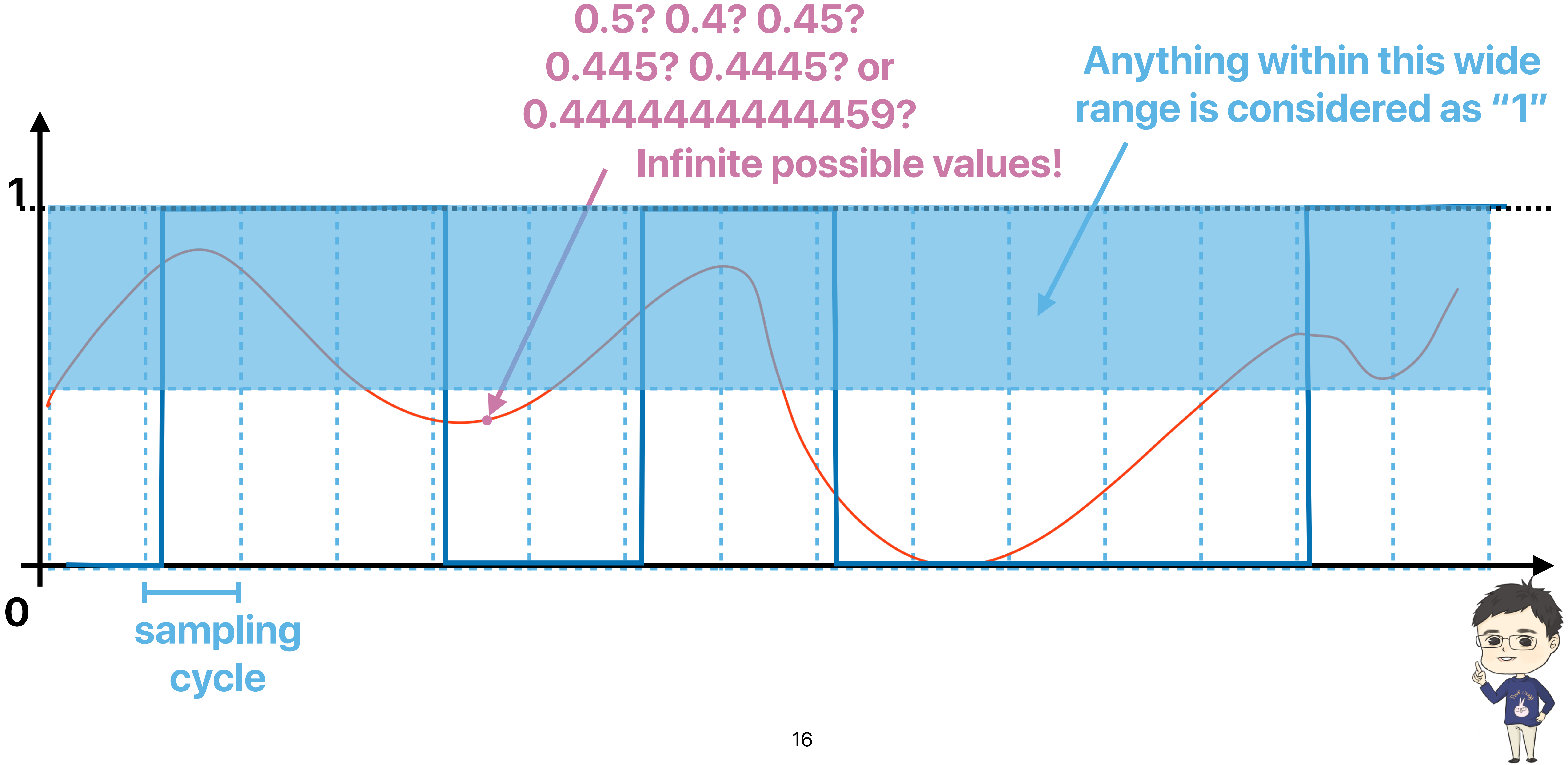

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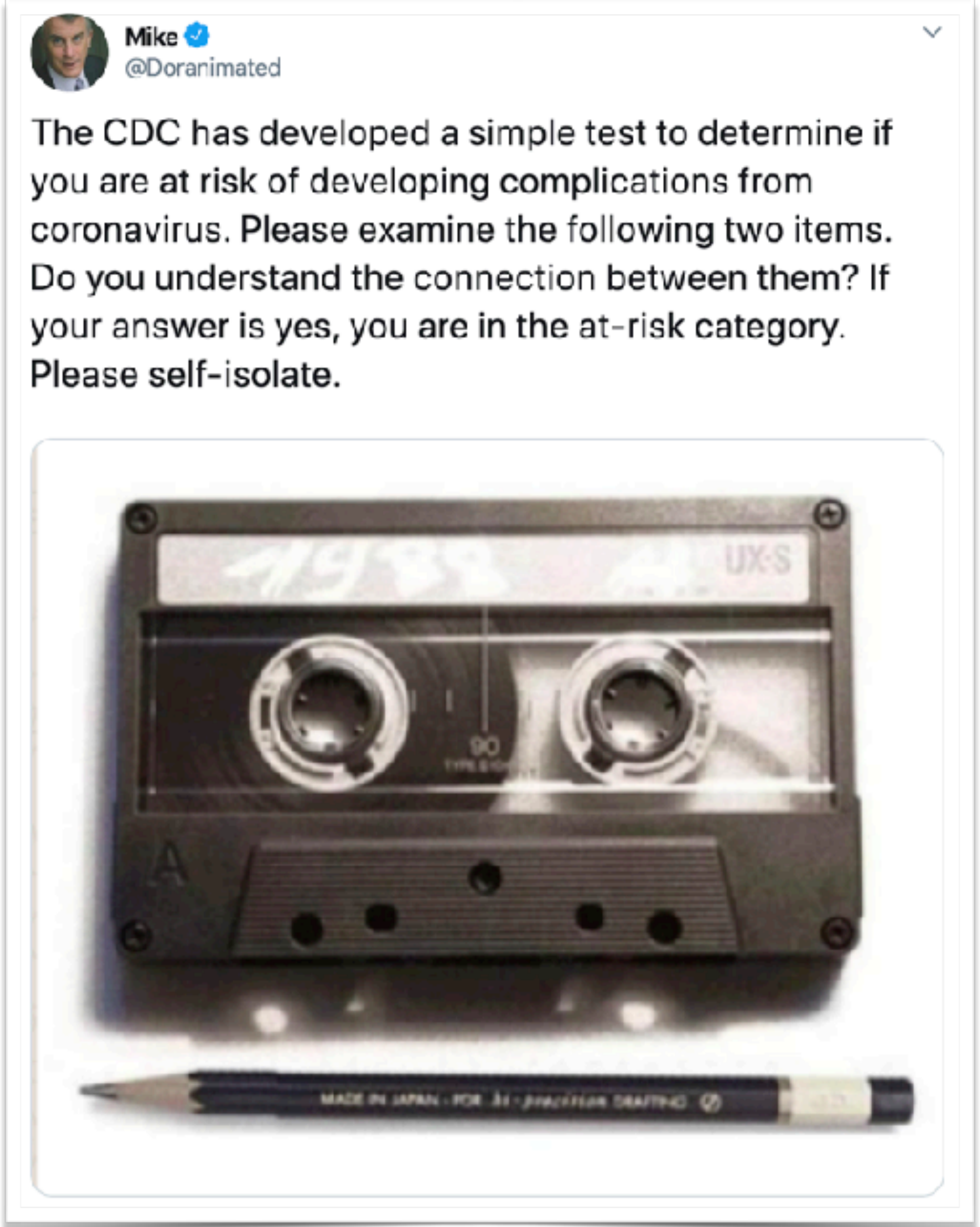

Analog data storage

https://www.youtube.com/watch?v=NVpOdpRDYF4

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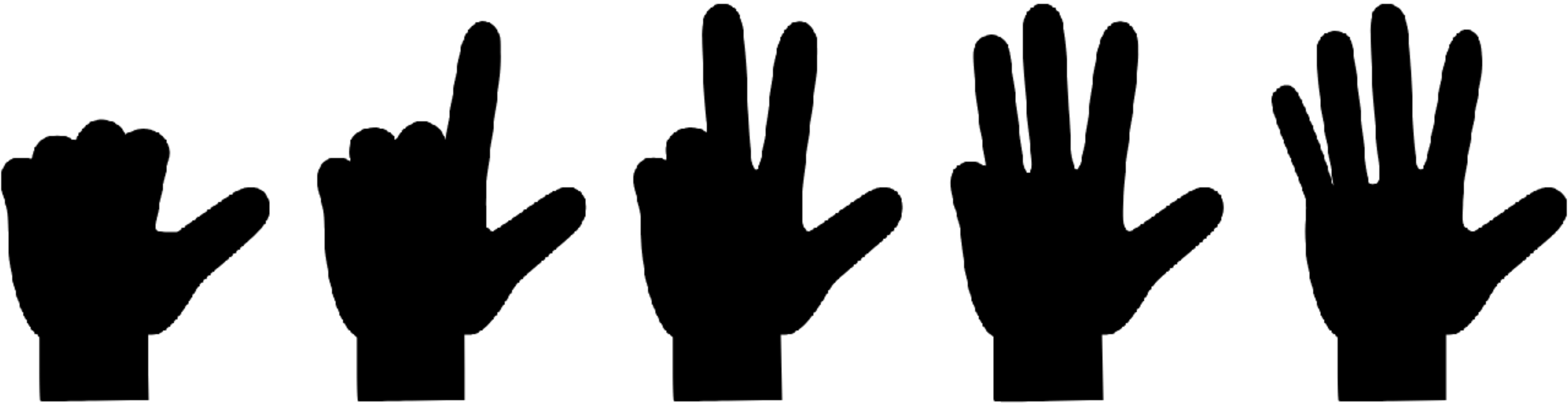
10-based number systems is the human-nature



10-based number system is popular since thousands of years ago

1: 𓏺

10: 𓎆

100: 𓍢

1000: 𓆼

10000: 𓂭

100000: 𓆐

1000000: 𓁨

𓆼𓆼 𓎆 𓎆 **= 2020**

0123456789

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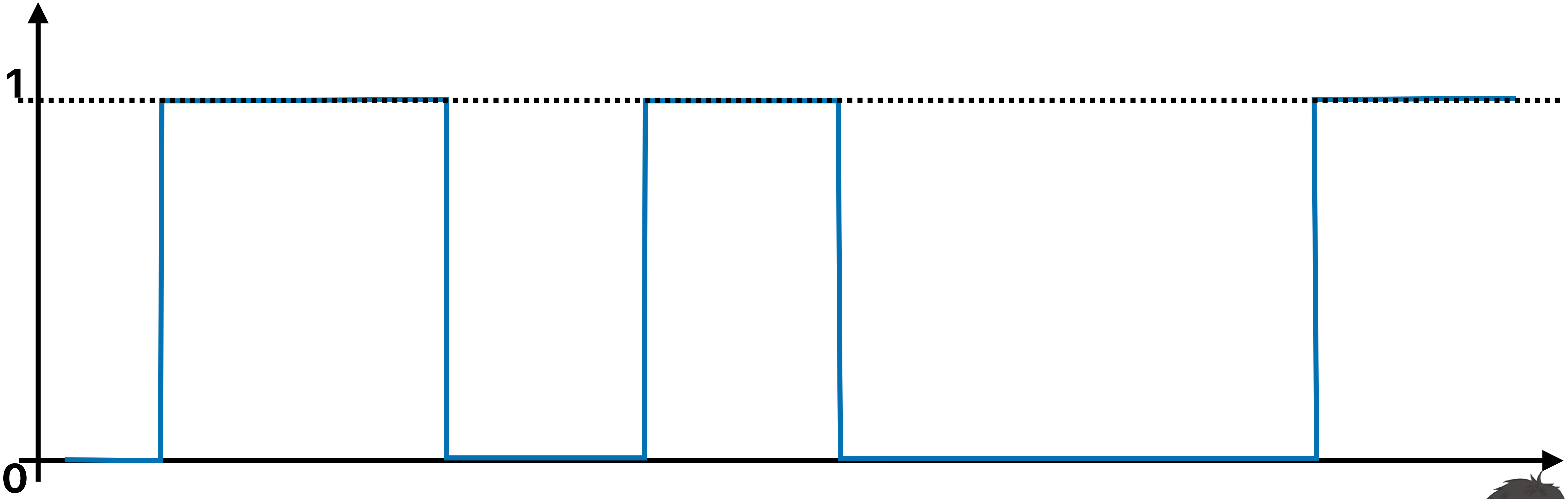
〇一二三四五六七八九

But digital circuits only have 0s and 1s...



Binary numbers

The brief history of binary numbers

- The modern binary number system was studied in Europe in the 16th and 17th centuries by Thomas Harriot, Juan Caramuel y Lobkowitz, and Gottfried Leibniz
- The concept of binary numbers have appeared earlier in multiple cultures including ancient Egypt, China, and India.
- Leibniz was specifically inspired by the Chinese I Ching.

The basic idea of a number system

- Each position represents a quantity; symbol in position means how many of that quantity
  - Decimal (base 10)
    - Ten symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
    - More than 9: next position
    - Each position is incremented by power of 10
  - Binary (base 2)
    - Two symbols: 0, 1
    - More than 1: next position
    - Each position is incremented by power of 2

$$10^2 \times \mathbf{3} + 10^1 \times \mathbf{2} + 10^0 \times \mathbf{1} = 300 + 20 + 1 = 321$$

$$2^3 \times \mathbf{1} + 2^2 \times \mathbf{0} + 2^1 \times \mathbf{0} + 2^0 \times \mathbf{1} = 1 \times 2^3 + 1 \times 2^0 = 1 \times 8 + 1 \times 1 = 9$$

urban DICTIONARY

TOP DEFINITION

Covidiot

Relating to the **2020** **Covid-19** virus:
Someone who ignores the warnings regarding public health or safety.
A person who hoards **goods**, denying them from their neighbors.

*Did you see that **covidiot** with 300 rolls of toilet paper in his **basket**?*
*That covidiot is **hugging** everyone she sees.*

#coronavirus #covid-19

by you'reandidiot March 16, 2020

How many does Prof. Usagi have?

- Prof. Usagi says that he has a few eggs that he cannot count with all his fingers. However, if we consider each finger as a position in a binary number, then we only need five fingers to count all of them. How many eggs he may have?
  A. 4
  B. 8
  C. 12
  D. 24
  E. 32

How many does Prof. Usagi have?

- Prof. Usagi says that he has a few eggs that he cannot count with all his fingers. However, if we consider each finger as a position in a binary number, then we only need five fingers to count all of them. How many eggs he may have?

More than 10

Some binary number needs 4 digits

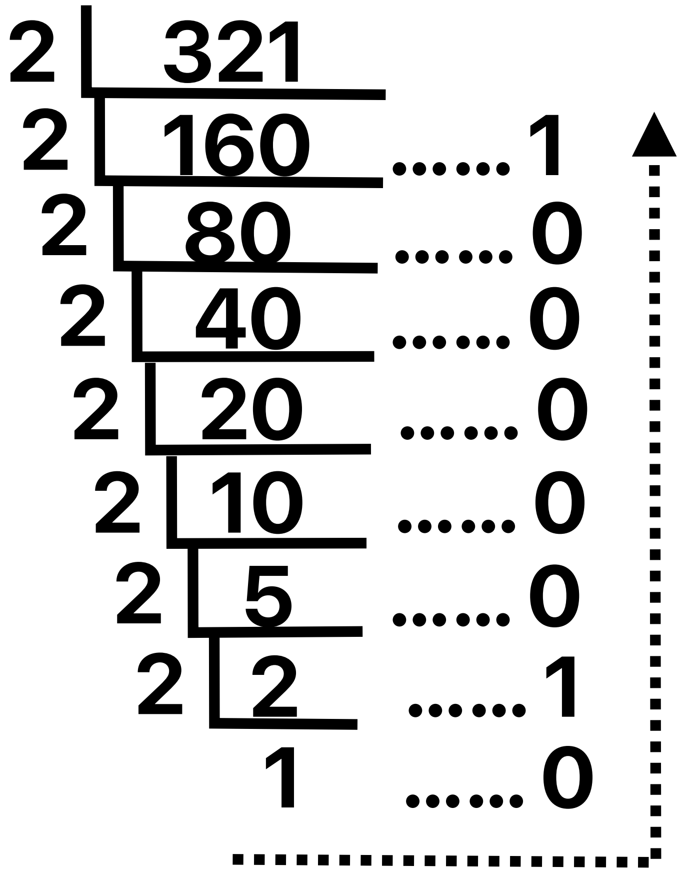
A. 4
B. 8
C. 12
D. 24
E. 32

$0b10000 < x < 0b11111$ and $10 < x$

$2^4+0=16 < x < 2^4+2^3+2^2+2^1+2^0=16+8+4+2+1=31$

$10 < 16 < x < 31$

Converting from decimal to binary



321 = 0b**101000001**

Other frequently used number systems

- Octal — base of 8
  - 8 symbols: 0, 1, 2, 3, 4, 5, 6, 7
  - More than 7: next position
  - Each position is incremented by power of 8
  - Easy conversion from binary — merge 3-digit into one
- Hexdecimal — base of 16
  - 16 symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
  - More than 15: next position
  - Each position is incremented by power of 16
  - Easy conversion from binary — merge 4-digit into one

321 = 0b**101000001**

321 = 0b**101 000 001**
= 0 **5 0 1**

321 = 0b**1 0100 0001**
= 0x**1 4 1**

Poll close in 1:30

Prof. Usagi's age?

- Prof. Usagi and some of you mentioned the age to each other and claim both of them are at their "21"s. Assume none of them are lying. Both of them completed their high school at the age of 18 (decimal) in their lives. Prof. Usagi got his bachelor's degree already without earlier completion through his student life, what number systems are they using?
  A. Prof. Usagi is using octal, the student is using decimal
  B. Prof. Usagi is using decimal, the student is using octal
  C. Prof. Usagi is using hexdecimal, the student is using decimal
  D. Prof. Usagi is using octal, the student is using hexadecimal
  E. Both of them are using decimal, Prof. Usagi is just incredibly young.

Prof. Usagi's age?

- Prof. Usagi and some of you mentioned the age to each other and claim both of them are at their "21"s. Assume none of them are lying. Both of them completed their high school at the age of 18 (decimal) in their lives. Prof. Usagi got his bachelor's degree already without earlier completion through his student life, what number systems are they using?
    A. Prof. Usagi is using octal, the student is using decimal
    B. Prof. Usagi is using decimal, the student is using octal
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Logic Design?

Logic design

COMPUTER TECHNOLOGY

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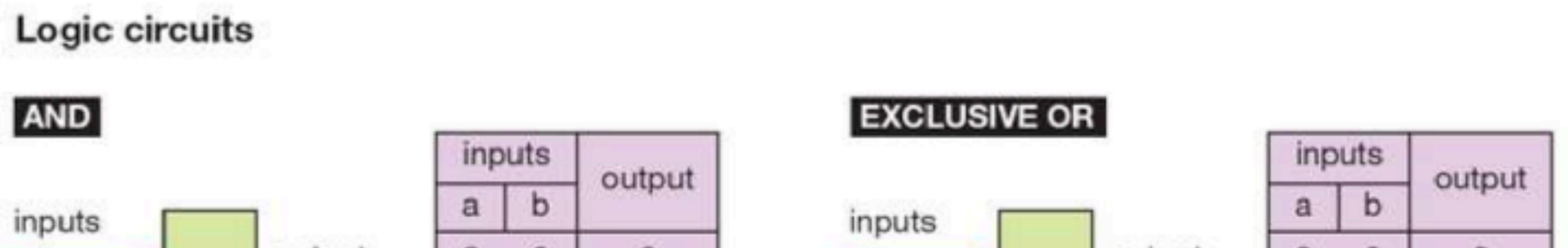


Beyond these, you will also learn...

Topics of this quarter

- Combinational Logic
  - Logic gates
  - Boolean Algebra
  - K-map
- Sequential Logic
  - Finite state machines
  - Clock
  - Flip-flops
- Datapath Components
  - Adder/mux/multipliers …
  - Registers
  - Counter/timers
- RTL Design
- Verilog

Why learning logic design?

What do you care when you're writing a program?

Algorithms
Data Structures
Software Engineering
Computer Hardware?
Programming
Languages
User Interfaces

How to solve this problem?

LeetCode Explore Problems Mock new Contest Articles Discuss Store

Description Solution Submissions Discuss (999+)

136. Single Number

Easy 3604 144 Add to List Share

Given a **non-empty** array of integers, every element appears *twice* except for one. Find that single one.

Note:

hash table?

Your algorithm should have a linear runtime complexity. Could you implement it without using extra memory?

Example 1:

```
Input: [2,2,1]
Output: 1
```

Example 2:

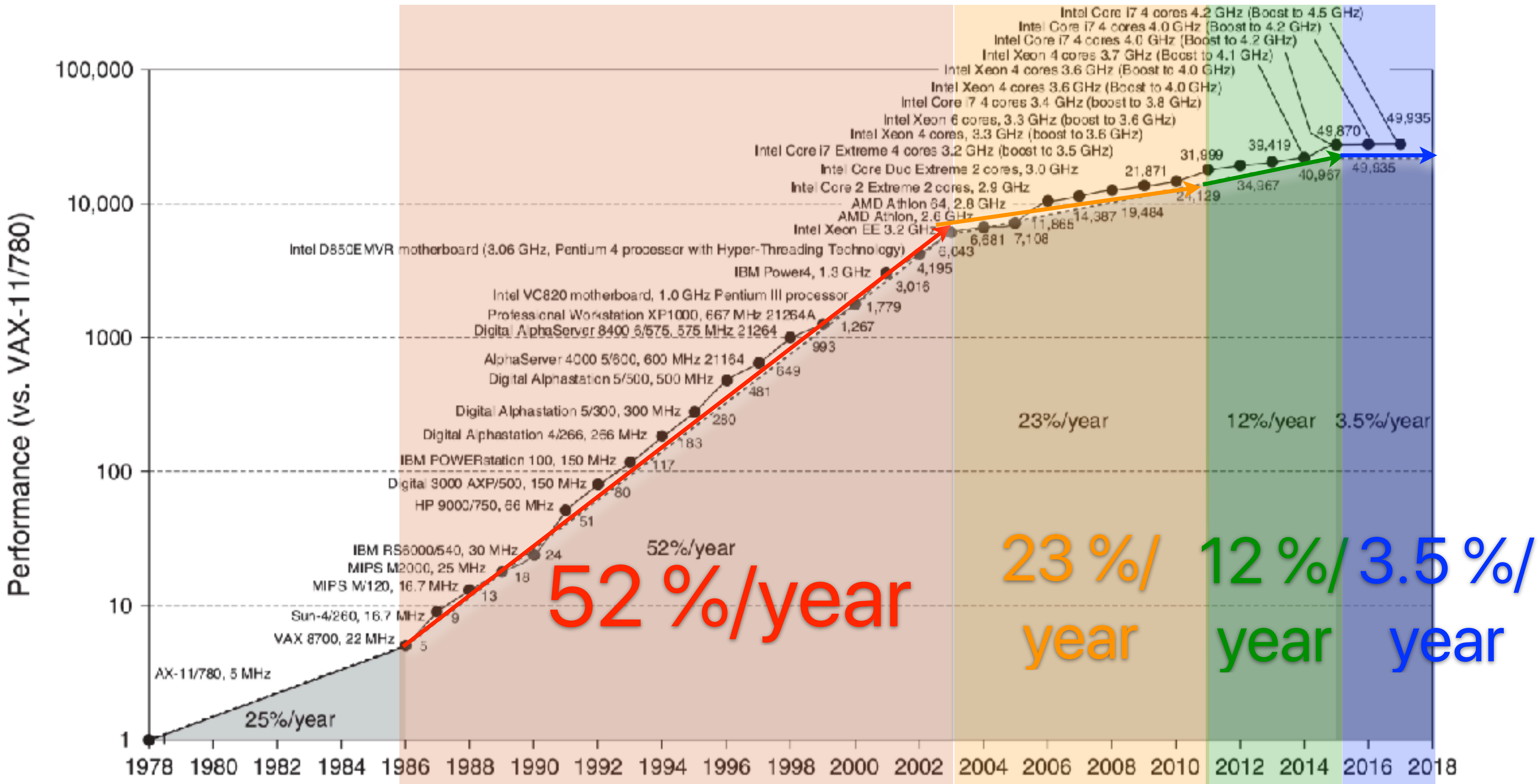
```
Input: [4,1,2,1,2]
Output: 4
```

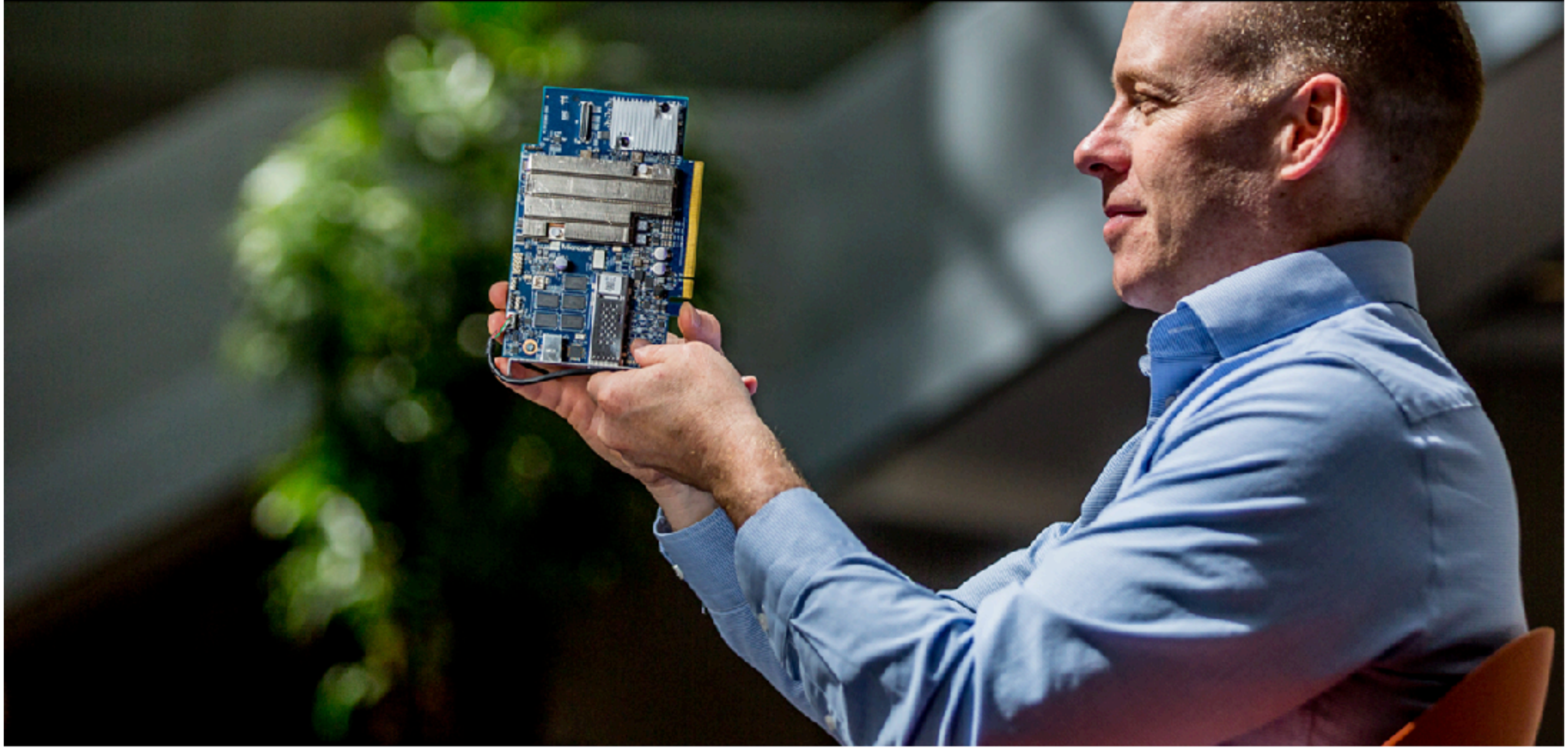
You need to have the concept of logic design!

```python
class Solution(object):
    def singleNumber(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        """
        a = 0
        for i in nums:
            a ^= i
        return a
```

```cpp
class Solution {
public:
    int singleNumber(vector<int>& nums) {
        return accumulate(nums.cbegin(), nums.cend(),
                          0, std::bit_xor<int>());
    }
};
```

Microprocessor performance does not scale well now





Real-time AI: Microsoft announces preview of Project Brainwave

AI & MACHINE LEARNING

An in-depth look at Google's first Tensor Processing Unit (TPU)

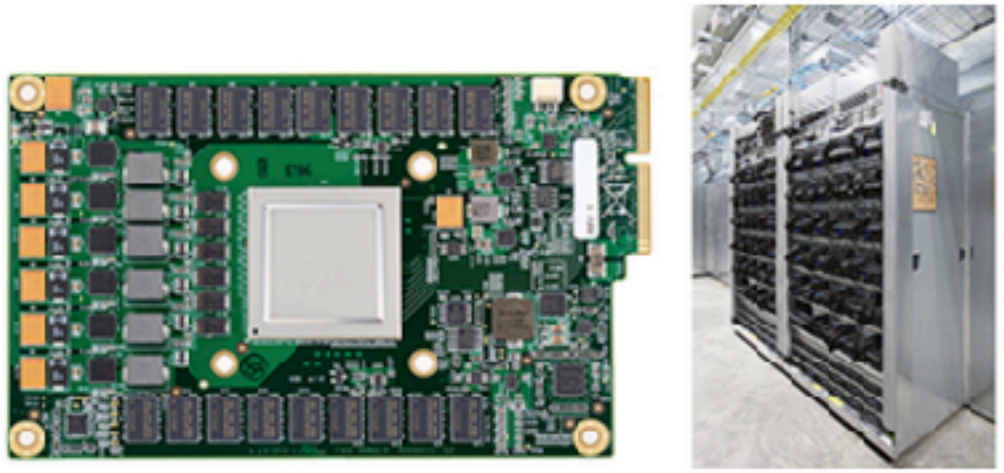
Kaz Sato
Staff Developer Advocate, Google Cloud

Cliff Young
Software Engineer, Google Brain

David Patterson
Distinguished Engineer, Google Brain

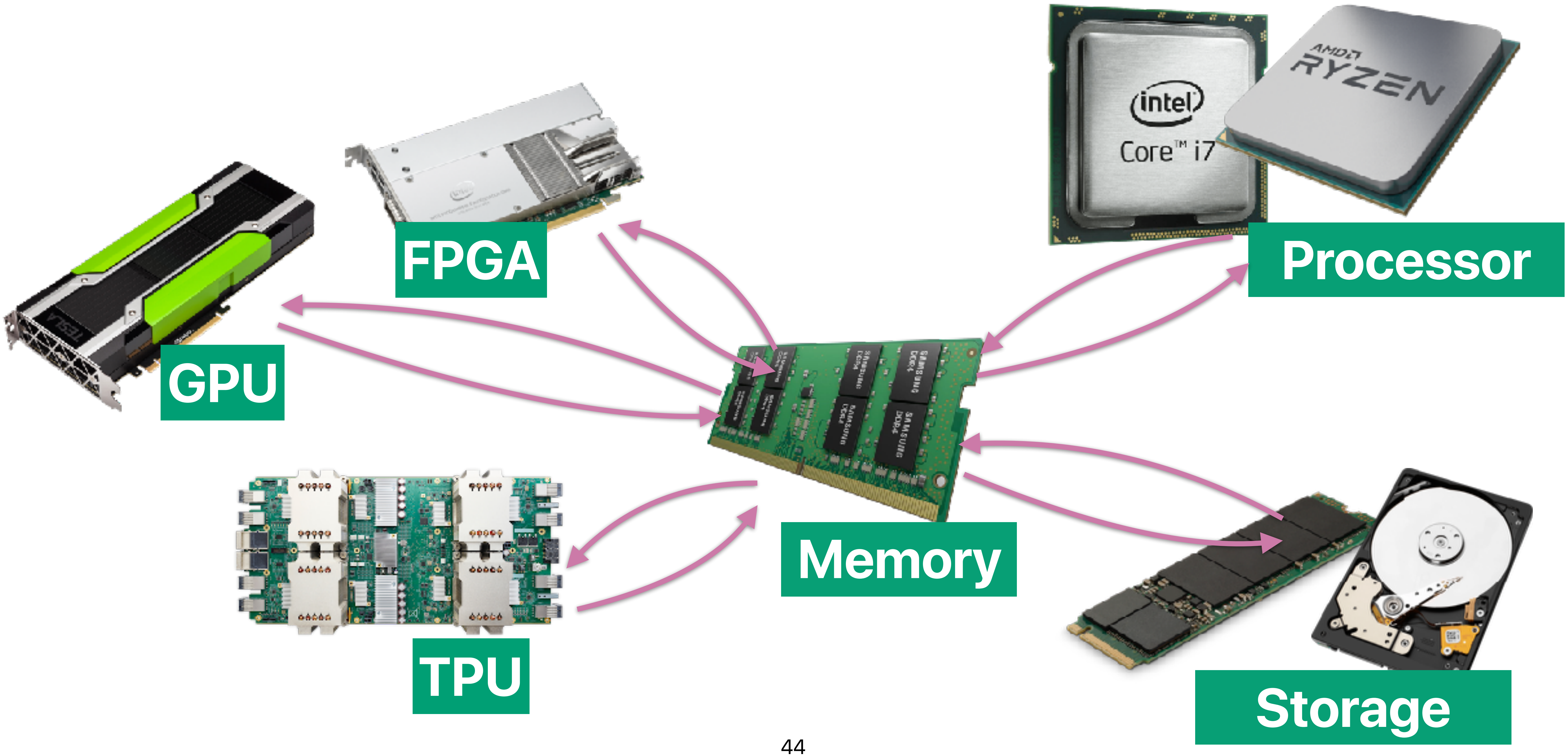
May 12, 2017

There's a common thread that connects Google services such as Google Search, Street View, Google Photos and Google Translate: they all use Google's Tensor Processing Unit, or TPU, to accelerate their neural network computations behind the scenes.



Google's first Tensor Processing Unit (TPU) on a printed circuit board (left); TPUs deployed in a Google datacenter (right)

Heterogeneous Computer Architecture



You have to interact or even have to design these hardware accelerators as in “software”

Learning eXperience

Our method

Read

- Textbook — **Digital design with RTL design VHDL and Verilog (2nd Edition)** by Prof. Frank Vahid
- Reading quiz on iLearn — due periodically before entering a new topic

Think

- We will have polls to encourage you think!
  - Let you practice
  - Bring out misconceptions

Learn

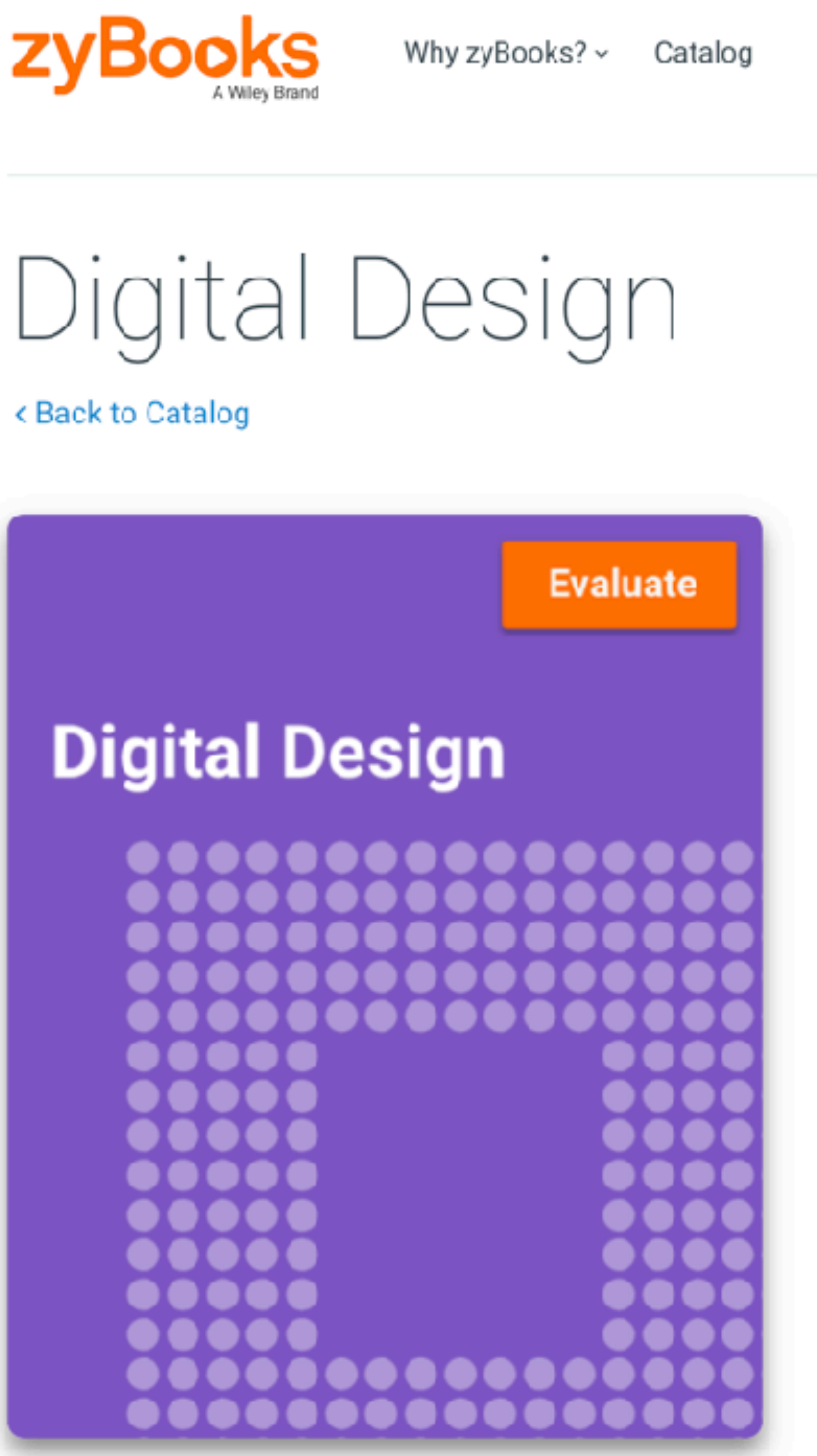
- We will learn more after thinking about those questions!

Practice

- We will have assignments help review what you learned during lectures!
- We will practice learned concepts into lab experiences!

Read

- Read the text before class!
  - Digital Design on ZyBooks
    - Prof. Frank Vahid gives us for free!
  - I'm not going to cover everything in class, but you are responsible for all the assigned text.
  - Complete of assigned chapters on ZyBooks
  - Take reading quizzes on iLearn
    - No time limitation until the deadline
    - No make up reading quizzes — we will drop probably one or two lowest at least



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- Sign in or create an account at learn.zybooks.com
- Enter zyBook code: UCREE120ATsengSpring2020
- Subscribe

Think

- During the lecture — I'll bring in activities to ENGAGE you in exploring your understanding of the material
  - Popup questions
  - Individual **thinking** — use your clicker to express your opinion
  - Whole-classroom **discussion** — we would like to hear from you

Learn

- You will learn after discussion/explanation on each concept
- Please join our discussions on Piazza as well!

Zoom Lecture Experience

Lecture	Poll	Discussion/Answer/ Questions	Lecture	Poll	D

Listen/Learn/Think/Mute	Think/Mute/ Answer	Raise Hands/ Unmute/Speak	Listen/Learn/Think/Mute	Think/Mute/ Answer	

Practice

- We will have 6 assignments on textbook materials
- We will have 6 labs
  - Using Verilog
  - Using simulation tools to verify and evaluate your design

Logistics

Course resource

- Lectures: TuTh 12:30p-1:50p @ https://ucr.zoom.us/j/436110795?pwd=UFF5emRQM2
- Schedule, slides on **course webpage —** https://www.escalab.org/classes/ee120a-2020sp
- Discussion on **piazza**: https://piazza.com/ucr/spring2020/ee_120a_001_20s
- Reading quizzes, lab submissions on **iLearn**: https://ilearn.ucr.edu/
- We do **youtube live streaming & lecture videos**: https://www.youtube.com/channel/UCAzJL6h2G-KEcRjVRwazjtQ
- Assignments/Reading on zyBooks.com

Tentative schedule (subject to change)

	Topic	Reading	Due
3/31/2020	Intro Lab #1 Release	zyBooks: Chapter #1.1-1.3	
4/2/2020	Boolean Algebra & Circuit Gates	zyBooks: Chapter #1.4-1.11	Reading Quiz #1
4/7/2020	Expressing circuit design in Boolean Equations	zyBooks: Chapter #1.12-1.17 & 2.1-2.5	Reading Quiz #2 Lab #1
4/9/2020	K-Map		Assignment #1
4/14/2020	Design Examples	zyBooks: Chapter #2.6-2.13, 3.1-3.6	Reading Quiz #3
4/16/2020	Adders		Lab #2
4/21/2020	Muxes, Carry-look ahead adders	zyBooks: Chapter #3.7-3.18	Reading Quiz #4
4/23/2020	Multipliers and ALUs		Assignment #2
4/28/2020	Sequential Network — latches	zyBooks: Chapter: #4	Reading Quiz #5
4/30/2020	Sequential Network — finite state machines		Lab #3
5/5/2020	Midterm Review		Assignment #3
5/7/2020	Midterm		
5/12/2020	Sequential Network examples (I)		Lab #4
5/14/2020	Sequential Network examples (II)	zyBooks: Chapter: #5	Reading Quiz #6
5/19/2020	Counters, Registers		Assignment #4
5/21/2020	Memory		Lab #5
5/26/2020	Counter, Register files, DRAM	zyBooks: Chapter: #6	Reading Quiz #7
5/28/2020	RTL Design (I)		Assignment #5
6/2/2020	RTL Design (II)		Lab #6
6/4/2020	Final Review		Assignment #6

Grading

- Reading quizzes in iLearn (8%)
  - Two attempts each quiz, take the average
  - Will drop the lowest
  - Check the website/iLearn for the due date
- Join the class (2%)
- 6 assignments throughout the quarter. (15%) — will drop the lowest
- 6 Labs (30%) — will drop the lowest
- Midterm (20%)
- Cumulative final (25%)

Instructor — Prof. Usagi (a.k.a. Hung-Wei Tseng)

- Website: https://intra.engr.ucr.edu/~htseng/
- E-mail: htseng @ ucr.edu
- BS/MS in **Computer Science**, National Taiwan University
- PhD in **Computer Science**, University of California, San Diego
- Research Interests
  - Intelligent storage devices
  - Non-volatile memory based systems
  - Near-data processing
  - Anything could accelerate applications
- Zoom office hour:
  TF 2p-3p
  https://ucr.zoom.us/j/232988601?pwd=bzFYU2MrN3ZJUE52YWZvdGdHZDMvdz09

Teaching Assistants

- Lab sessions —
  - Will release videos on Tuesdays — Lab #1 is available after this lecture!
  - Please attend your registered session virtually
    - Wed 9a-12p — Yibo Liu
    - Fri 9a-12p — Luting Yang
  - Lab sessions are technically group office hours.
    - No lab lectures during that time — please watch videos first!
    - Jump in whenever you have a question.

What's on iLearn?

Journals

Create and manage journals that can be assigned to each user in a group for the instructor.

McGraw-Hill Higher Education

Access and Manage McGraw-Hill products for this course through Blackboa

MediaAMP

Mediasite Course Catalog

Launch the Mediasite Catalog for this course.

My Grades

Displays detailed information about your grades.

Course Materials

Build Content | Assessments | Tools

Course Webpage

Please refer to this page for complete schedule, slides and due date information.

Zoom Online Lecture

Please navigate to https://ucr.zoom.us/j/436110795?pwd=UFF5emRQM2J6STdhQTB3VDk4QUIMUT09 for online lecture

Youtube Channel

Archived lectures

Lab lectures

Youtube LiveStreaming

Textbook

Please click the link to access zyBooks. Please use ucr.edu e-mail to have $0 subscription.

Piazza

Office Hours

Luting Yang (M 2p-4p)

https://ucr.zoom.us/j/890527239

Prof. Usgai (TuF 2p-3p)

https://ucr.zoom.us/j/232988601?pwd=bzFYU2MrN3ZJUE52YWZvdGdHZDMvdz09

Yibo Liu (W 12p-2p)

https://ucr.zoom.us/j/5578647397

Grading

- You can see your grades on iLearn.
- Errors in grading
  - If you feel there has been an error in how an assignment or test was graded, you have one week from when the assignment is return to bring it to our attention. You must submit (via email to the instructor and the appropriate TAs) a written description of the problem. Neither I nor the TAs will discuss regrades without receiving an email from you about it first.
- For arithmetic errors (adding up points etc.)
  - you do not need to submit anything in writing, but the one week limit still applies.

Academic Honesty

- Don’t cheat.
  - Cheating on a test will get you an F in the class and no option to drop, and a visit with your college dean.
  - Cheating on homework means you don’t have to turn them in any more, but you don’t get points either. You will also take at least 25% penalty on the exam grades.
- Copying solutions of the internet or a solutions manual is cheating
  - They are incorrect sometimes
- Review the UCR student handbook
- When in doubt, ask.


2017 Spring @ NC State
2017 Fall @ NC State
Let's take a photo now!
2020 Spring @ UCR
2016 Fall @ NC State
2018 Spring @ NC State
2016 Summer @ UCSD
2019 Spring @ NC State
2019 Winter @ UCR
2016 Spring @ UCSD
2019 Summer II @ UCSD
2014 Summer @ UCSD
2018 Fall @ NC State
2012 Summer @ UCSD
2019 Summer I @ UCSD
2019 Fall @ UCR

Announcement

- Lab #1 is online
  - Please attend your assigned session for load balancing
  - Submit your report online through iLearn
  - Due 4/7
- Reading quiz #1 is online
  - Due this Thursday
  - Through iLearn