CS/EE120A: Logic Design

Jia Chen
jiac@ucr.edu

Slides adopted from Hung-Wei Tseng

Logic Design?

Logic design

computer technology

Print | Cite | Share | More

BY **The Editors of Encyclopaedia Britannica** View Edit History

FULL ARTICLE

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.

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

“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

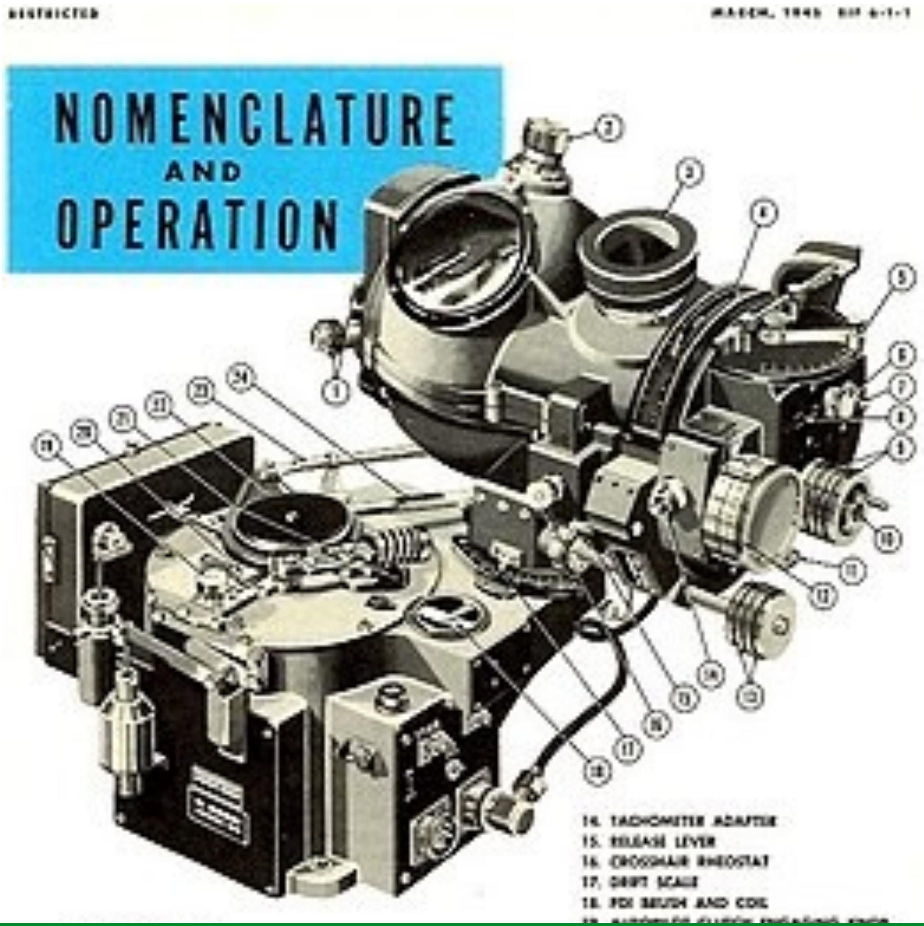
specifically : a programmable usually electronic device that can store, retrieve, and process data

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

Digital Computers

Analog Computers

The Antikythera mechanism, dating between 150 and 100 BC, was an early analog computer: calculate astronomical positions



The Norden bombsight was a highly sophisticated optical/mechanical analog computer used by the United States Army Air Force during World War II to aid the pilot of a bomber aircraft in dropping bombs accurately.

MONIAC (**Monetary National Income Analogue Computer**), was created in 1949 by the New Zealand economist Bill Phillips to model the national economic processes of the UK.

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 an irreducible units. These technolo investigated in the last few years. T 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

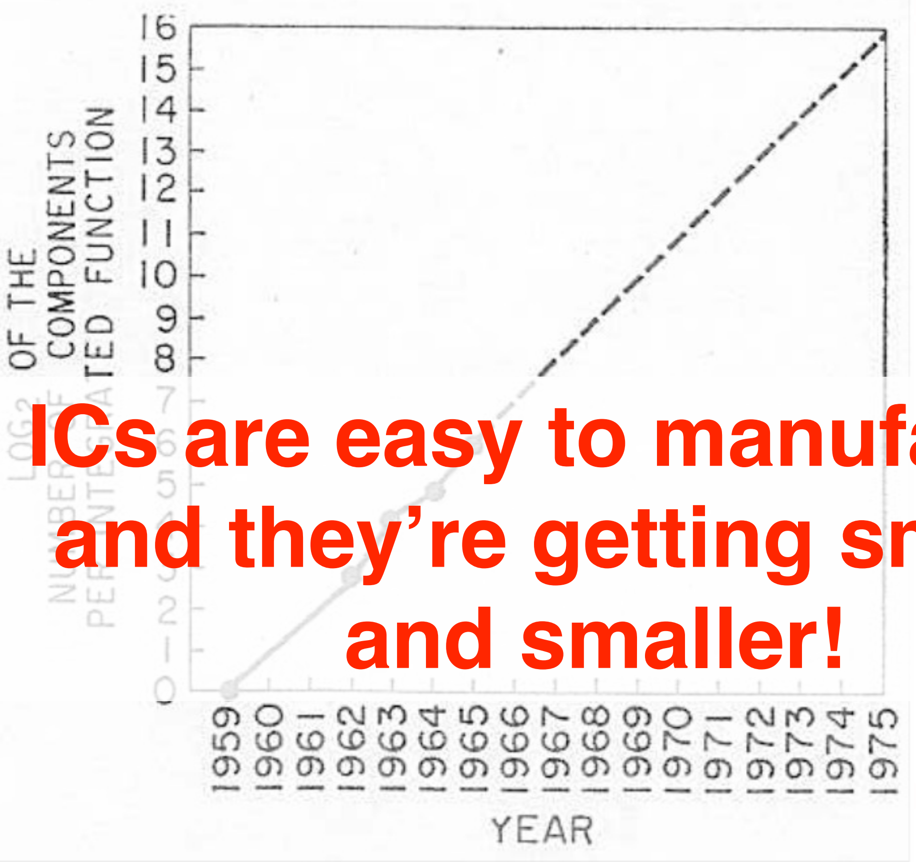
The establishment

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

stablish

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!

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

Reliability coun

In almost 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 Law is the most impo h perf

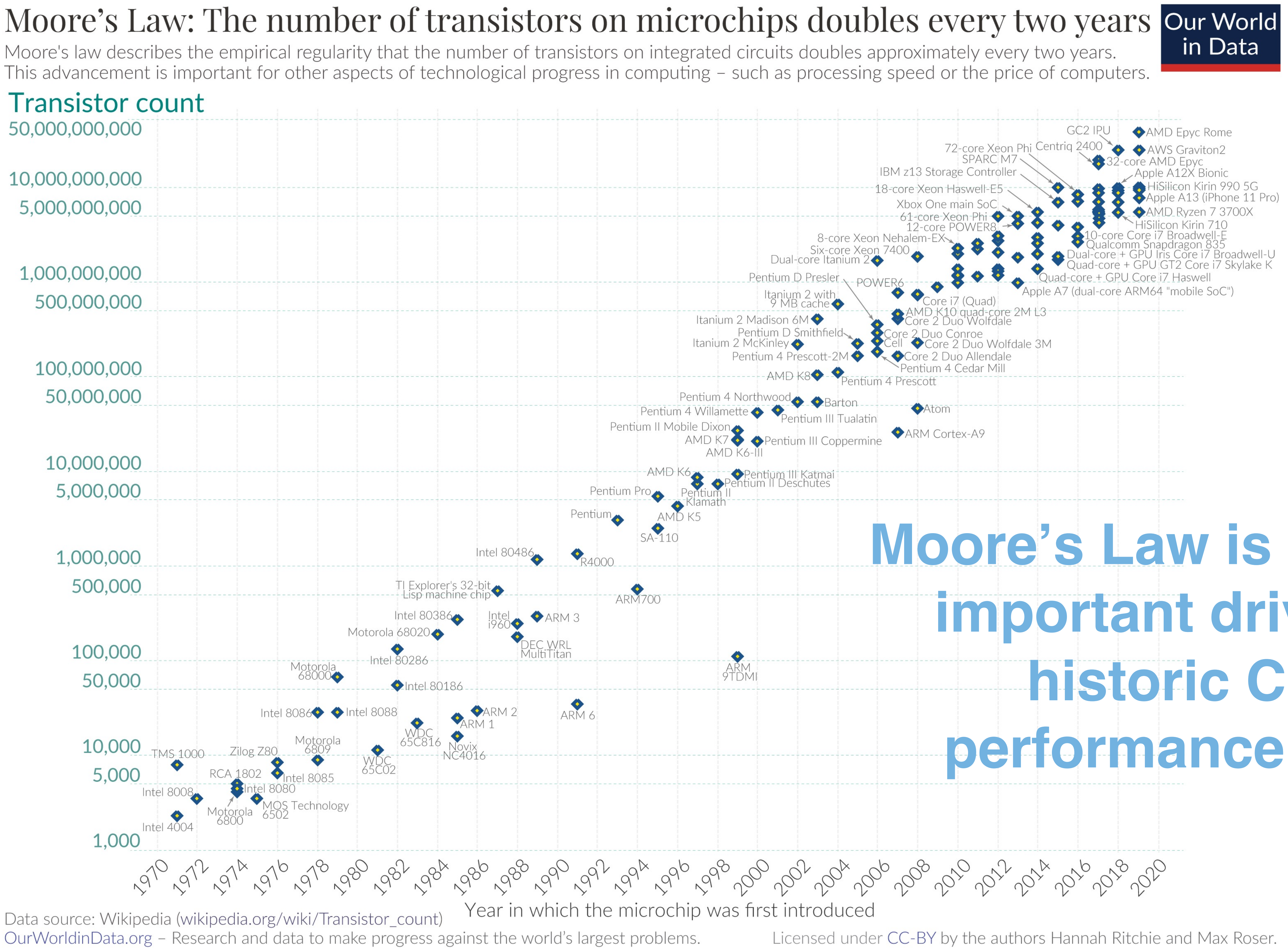
Day of reckoning

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 re components onto integrated circuits", Electronics 38 (8) .

Moore’s Law



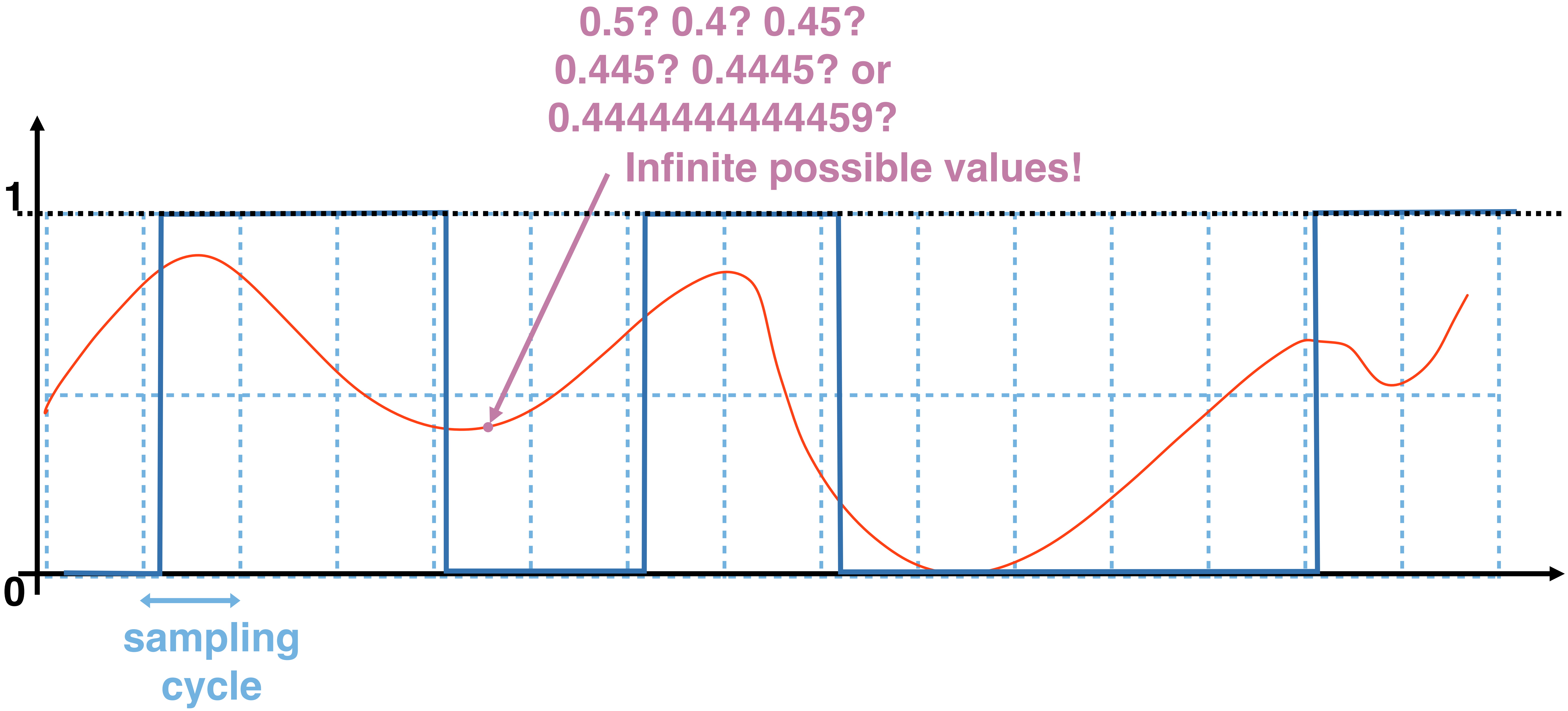
Moore’s Law is the most important driver for historic CPU performance gains

A semi-log plot

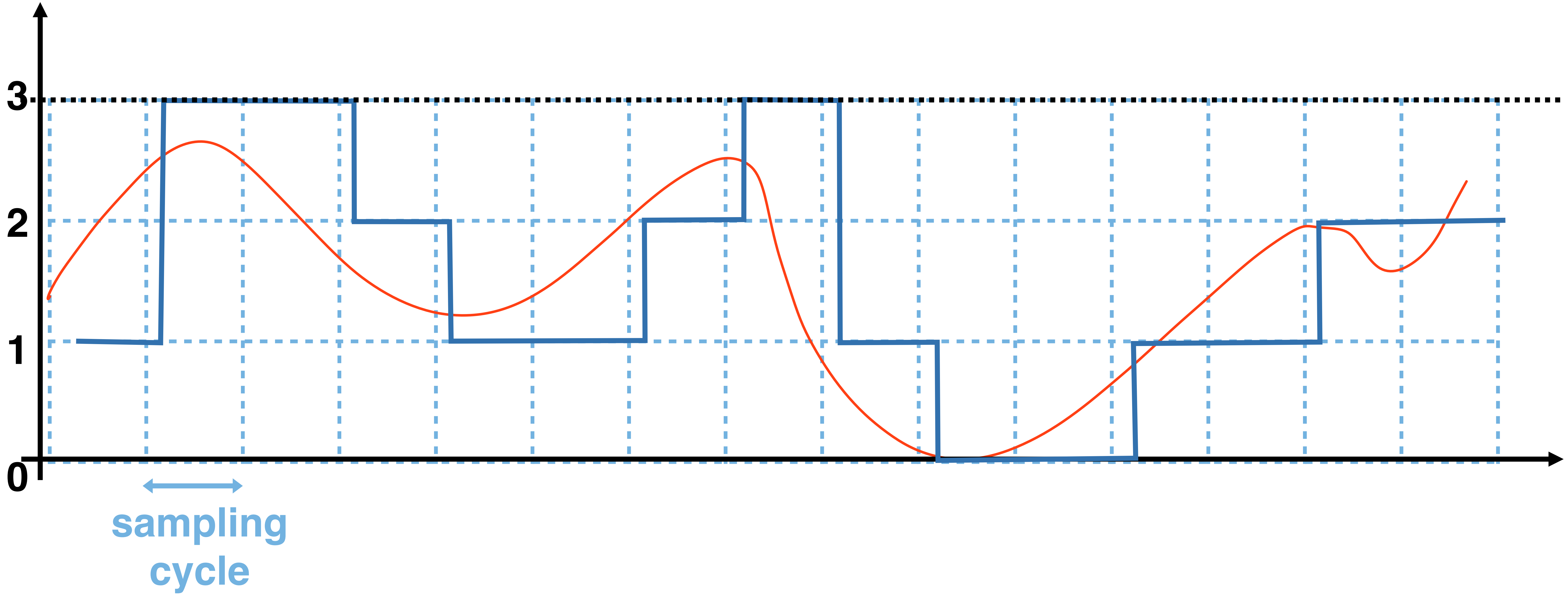
Why are digital computers more popular now?

- 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

Analog v.s. digital signals



Analog v.s. digital signals

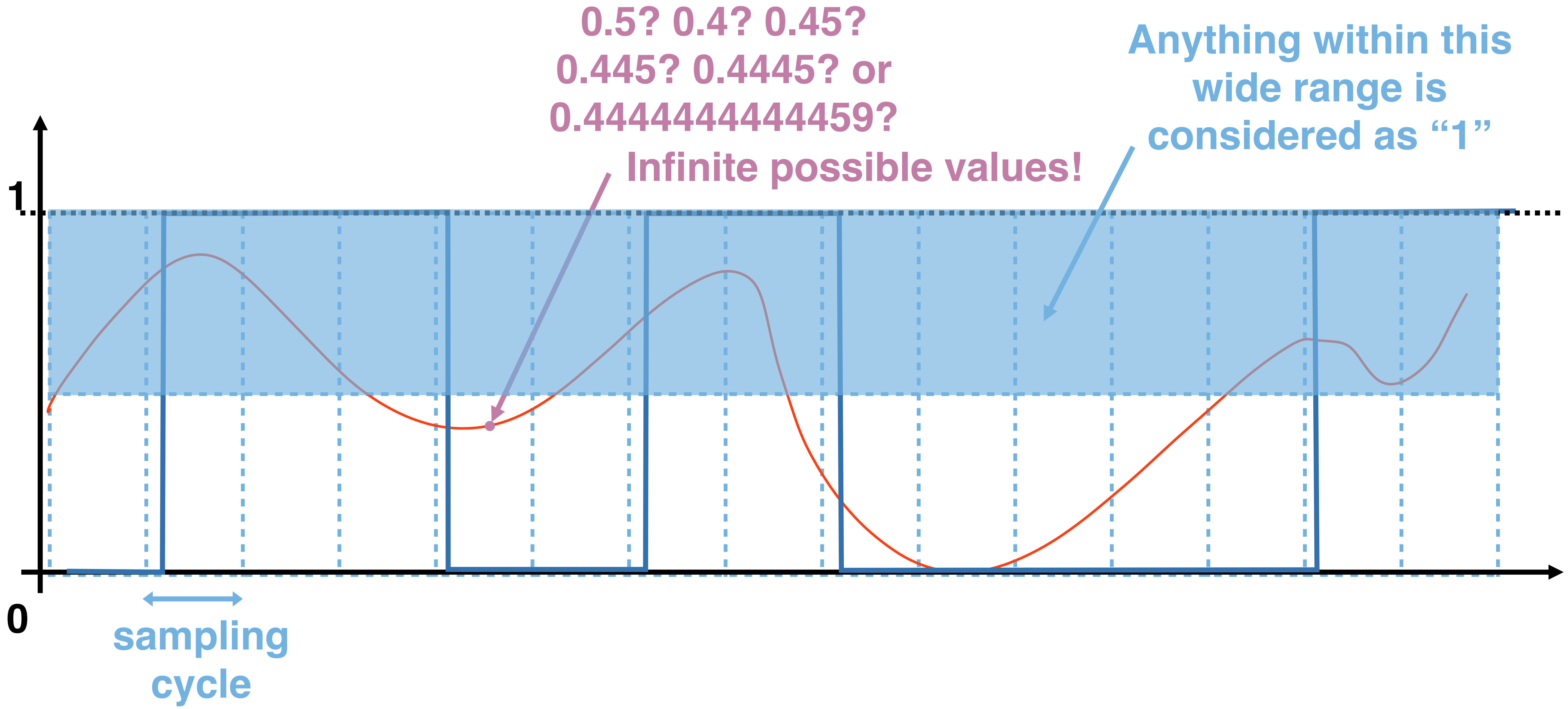


Why are digital computers more popular now?

- 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

Analog v.s. digital signals



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

Analog data storage

VS

Digital data storage

Samples per second

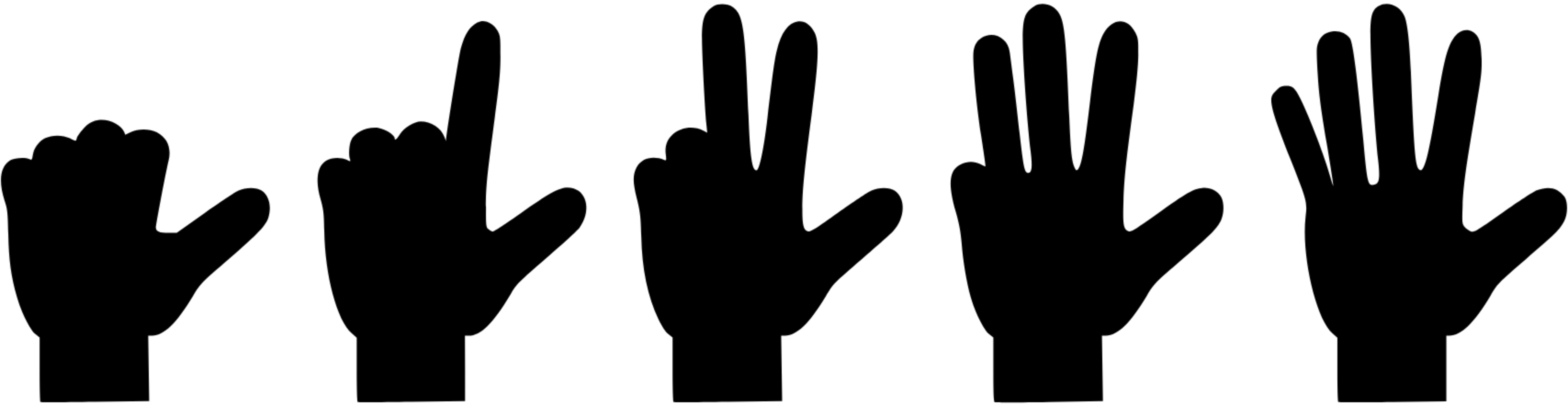
- CD Audio = 44,100
- DVD Audio = 192,000

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

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

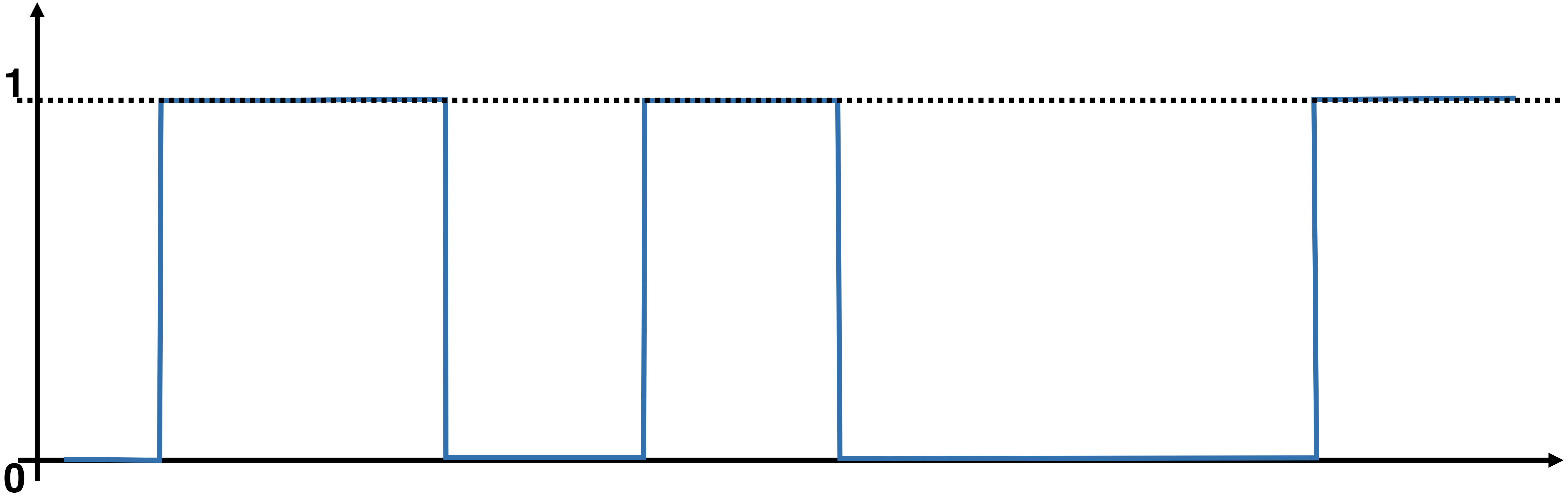
10000: 𓂭

100000: 𓆐

1000000: 𓁨

𓆼𓆼 𓎆 𓏺 = 2021

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

$$\begin{array}{ccccc} 10^2 & & 10^1 & & 10^0 \\ \times & & \times & & \times \\ \mathbf{3} & + & \mathbf{2} & + & \mathbf{1} \end{array} \quad \begin{array}{l} =300 \\ +20 \\ +1 \\ =321 \end{array}$$

$$\begin{array}{ccccccc} 2^3 & & 2^2 & & 2^1 & & 2^0 \\ \times & & \times & & \times & & \times \\ \mathbf{1} & + & \mathbf{0} & + & \mathbf{0} & + & \mathbf{1} \end{array} \quad \begin{array}{l} =1 \times 2^3 \\ +1 \times 2^0 \\ =1 \times 8 \\ +1 \times 1 \\ =9 \end{array}$$

Converting from decimal to binary

```
2 | 321
2 | 160  ...... 1
2 | 80   ...... 0
2 | 40   ...... 0
2 | 20   ...... 0
2 | 10   ...... 0
2 | 5    ...... 0
2 | 2    ...... 1
    1    ...... 0
```

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

321 = 0b**101000001**

321 = 0b**101 000 001**

= 0 **5 0 1**

- 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**1 0100 0001**

= 0x**1 4 1**

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 (register-transfer level) Design
- Verilog

Learning eXperience

Our method

Read

- Textbook — **Digital design with RTL design VHDL and Verilog (2nd Edition)** by Prof. Frank Vahid

Think

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

Learn

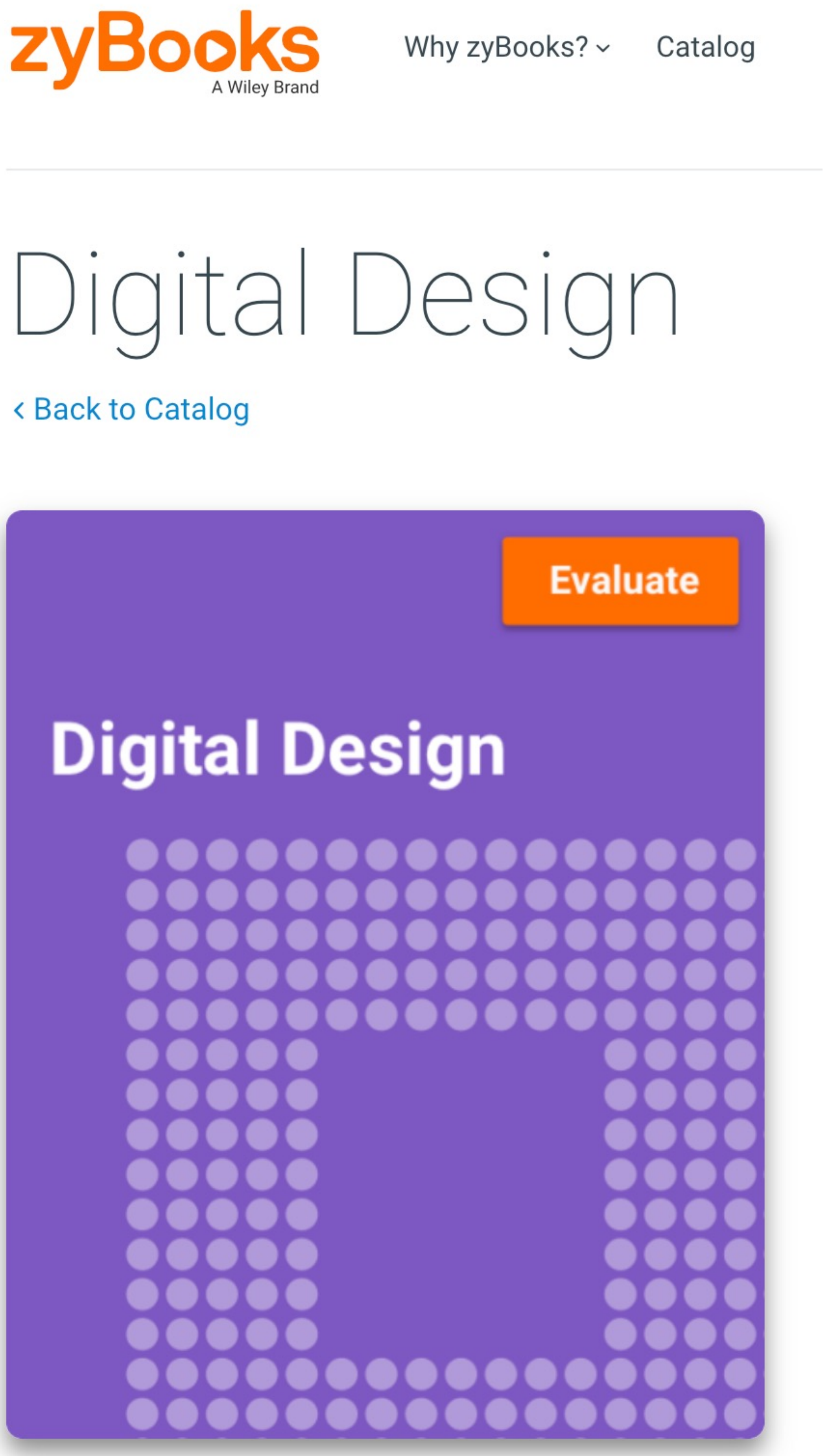
- We will learn more after thinking about those questions!

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 and/or after class!
  - Digital Design on ZyBooks
    - Prof. Frank Vahid gives us for free!



Subscribe to your textbook!

- Sign in or create an account at learn.zybooks.com
- Enter zyBook code: **UCRCS120AEE120AChenFall2021**
- 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!

Practice

- We will have 4 homework assignments
- We will have 6 labs
  - Using Verilog
  - Using simulation tools to verify and evaluate your design
  - Testing the results in FPGA Evaluation Board

Logistics

- Online lectures: MWF 1:00-1:50pm

  Zoom link is announced on Canvas

- Instructor: Jia Chen

  Email: jiac@ucr.edu
  Office location: Bourns Hall A 149
  Office hours: Wednesday 3-5pm via Zoom or by appointment

  Zoom link is announced on Canvas

- All the materials/announcements can be found on Canvas

Grading

- Homework: 20%
- Labs: 30% (will drop the lowest)
- Midterm: 20%
- Final exam: 30%

Teaching Assistants

- Lab sessions —
  - Please attend your registered session in person
    - MTu 8:00-10:50am — Hengyun (Henry) Liu
    - WTh 8:00-10:50am —
  - Brief lab lectures in the beginning of the time
  - Jump in whenever you have a question
  - Office hours: 2 hours per TA per week