

# CS 152/252A Computer Architecture and Engineering

Sophia Shao

## Lecture 26: Finale

**A New Golden Age for Computer Architecture: History, Challenges, and Opportunities**

We began our Turing Lecture June 4, 2018 with a review of computer architecture since the 1960s. In addition to that review, here, we highlight current challenges and identify future opportunities, projecting another golden age for the field of computer architecture in the next decade, much like the 1980s when we did the research that led to our award, delivering gains in cost, energy, and security, as well as performance.

"Those who cannot remember the past are condemned to repeat it.“ George Santayana, 1905

turing lecture

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Innovations like domain-specific hardware, enhanced security, open instruction sets, and agile chip development will lead the way.

BY JOHN L. HENNESSY AND DAVID A. PATTERSON

A New Golden Age for Computer Architecture

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*"Those who cannot remember the past are condemned to repeat it."* —George Santayana, 1905

Software talks to hardware through a vocabulary called an instruction set architecture (ISA). By the early 1960s, IBM had four incompatible lines of computers, each with its own ISA, software stack, I/O system, and market niche—targeting small business, large business, scientific, and real time, respectively. IBM

engineers, including ACM A.M. Turing Award laureate Fred Brooks, Jr., thought they could create a single ISA that would efficiently unify all four of these ISA bases.

They needed a technical solution for how computers as inexpensive as

» key insights

- Software advances can inspire architecture innovation.
- Elevating the hardware/software interface creates opportunities for architecture innovation.
- The marketplace ultimately settles architecture debates.

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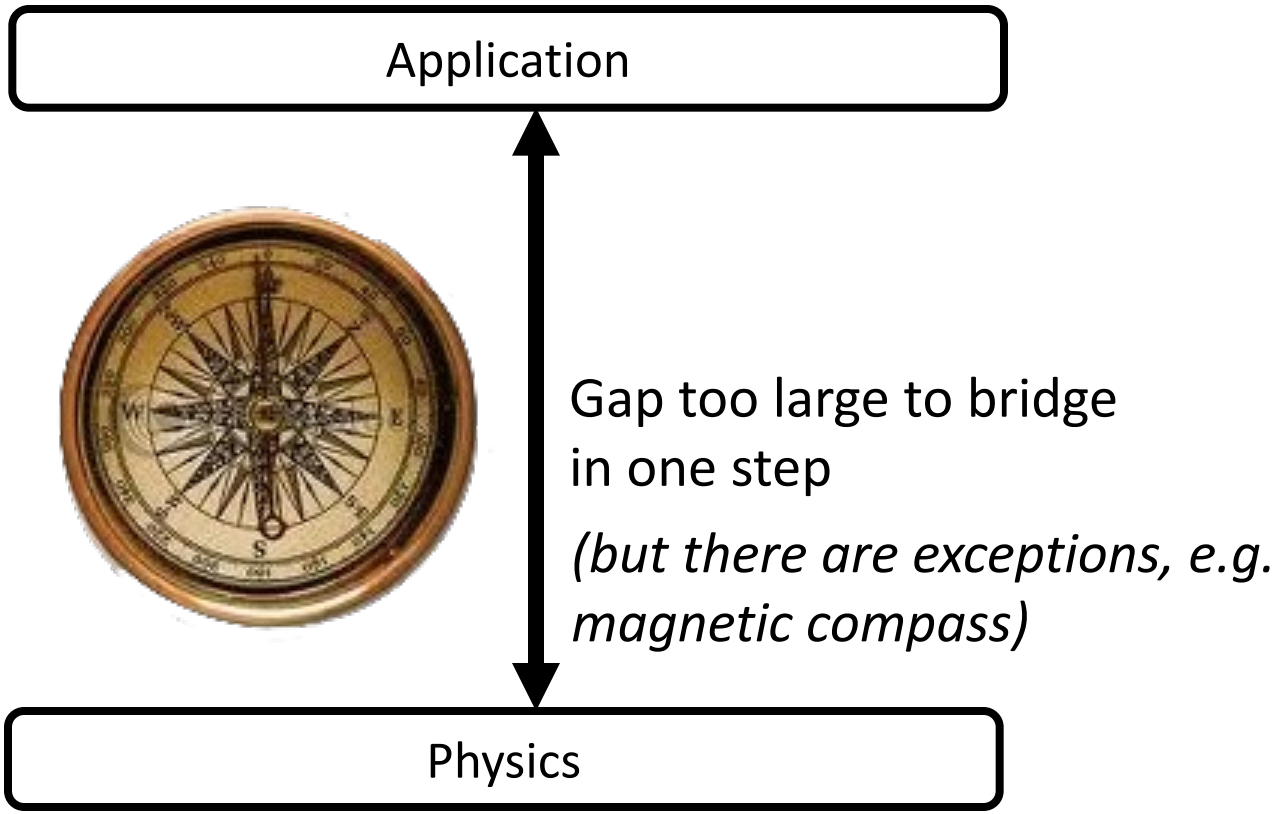
https://cacm.acm.org/magazines/2019/2/234352-a-new-golden-age-for-computer-architecture/fulltext

# What is Computer Architecture?




In its broadest definition, computer architecture is the *design of the abstraction layers* that allow us to implement information processing applications efficiently using available manufacturing technologies.

# Abstraction Layers in Modern Systems


Application

Algorithm

Programming Language

Operating System/Virtual Machines

Instruction Set Architecture (ISA)

Microarchitecture

Gates/Register-Transfer Level (RTL)

Circuits

Devices

Physics

UCB EECS Courses

CS170

CS164

CS162

CS152/252A

EECS151/251

EE143

# Span of CS152

- Early simple machines, microcoding, pipelining, bypassing, caching, prefetching, address translation and protection, virtual memory, complex pipelining, out-of-order execution, register renaming, branch prediction, VLIW, vectors/SIMD, GPUs, cache coherence, memory consistency models, synchronization, virtual machines, warehouse-scale computers.

- Just an introduction to main concepts in modern computer architecture, could easily spend a semester course on any one topic!

# Computer Architecture in 2023

- Explosion of interest in custom architectures due to end of transistor scaling
  - Alibaba, Apple, Amazon, Bytedance, Facebook, Google, Huawei, Microsoft, Qualcomm, Tencent, Tesla, design and build their own processors and SoCs!
  - Full employment for computer architects.
- But need to learn about application domains
  - Cannot just work with precompiled binaries anymore!
- Get involved in research projects
  - SLICE: Specialized Ecosystem Research Center
  - BWRC: Berkeley Wireless Research Center

# CS152 Administrivia

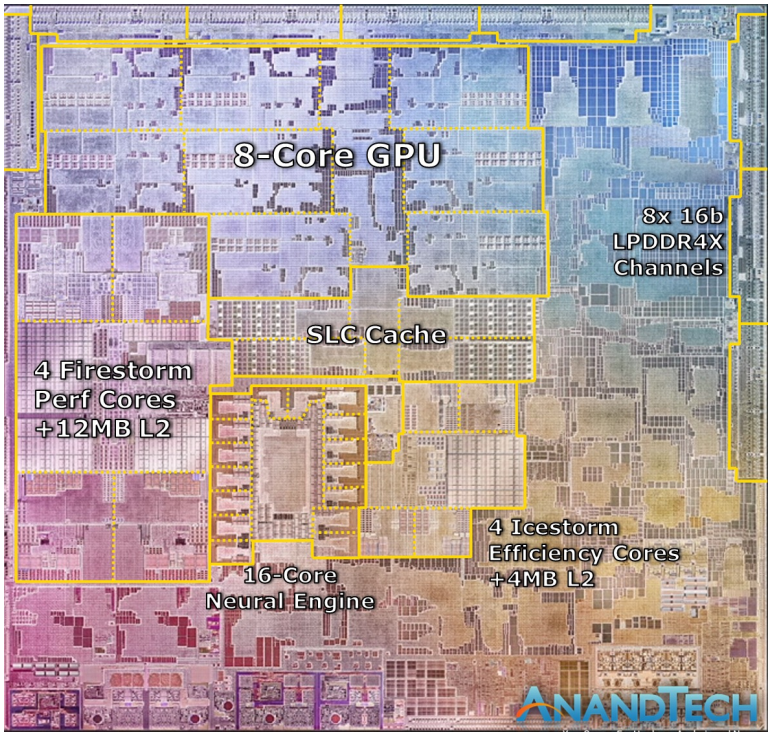
- Midterm 2 is done!
- HW5 due 4/27
- Lab5 due 5/2
- Course Survey (152/252A)
  - https://course-evaluations.berkeley.edu/berkeley/
  - We VALUE your feedback!
  - Tell us your experience!
  - Tell us what worked and what could be improved!
  - Extra credits:
    - 0.5 pt if you submit a confirmation screenshot through gradescope
    - 0.5 more pt for everyone who complete the survey if we hit 80% response rate!

# CS252 Administrivia

- Wednesday 5/3 Project Presentation
  - 15-min/team
- Sunday 5/7
  - Final report due
  - 10-page max

# Field has advanced!

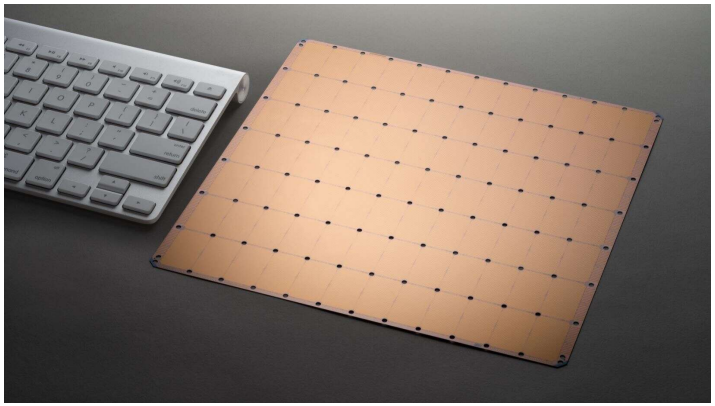
- Apple Announces The Apple Silicon M1: Ditching x86




https://www.anandtech.com/show/16226/apple-silicon-m1-a14-deep-dive

# Field has advanced!

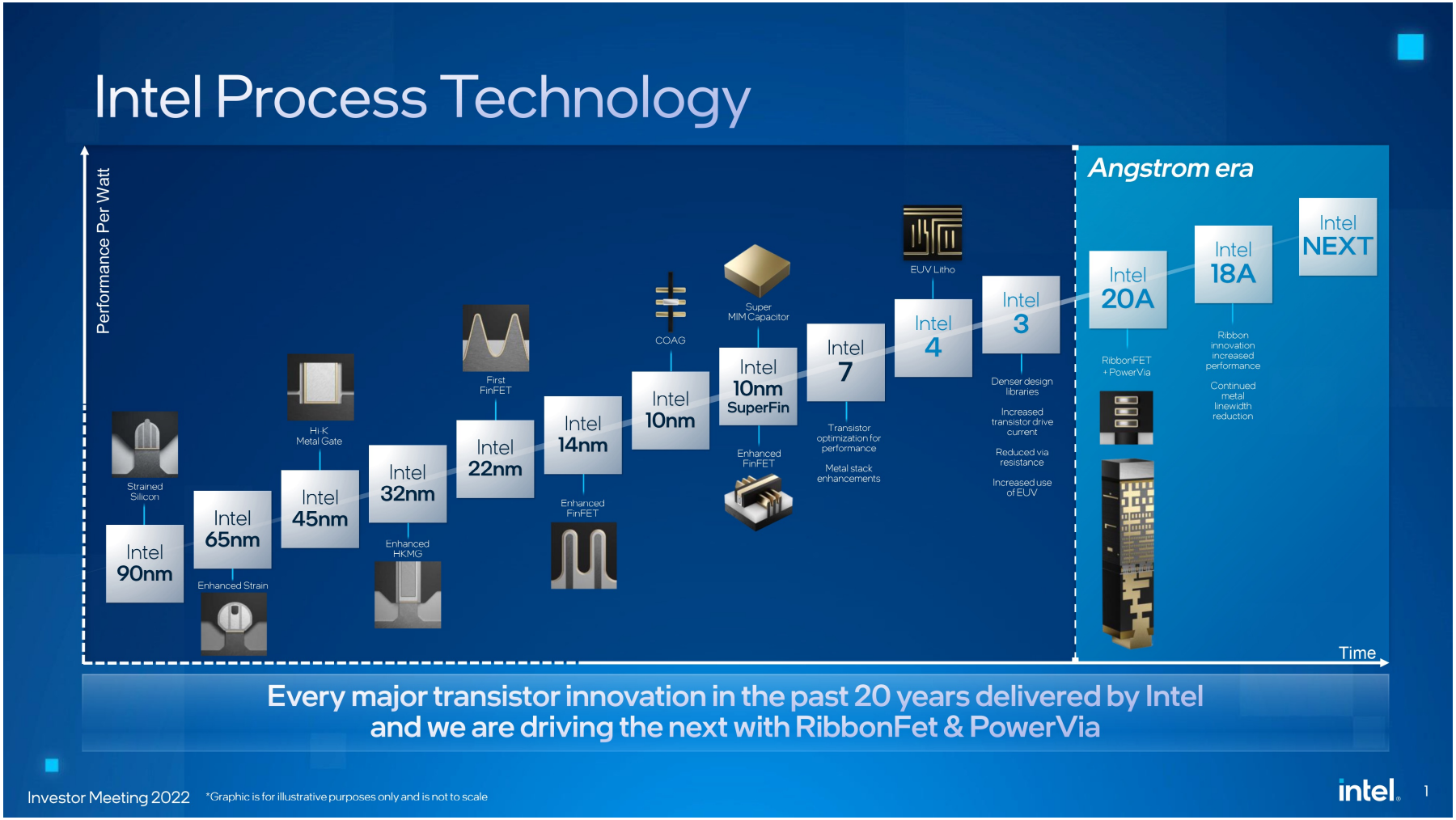
- Cerebras: Wafer-scale Computing!



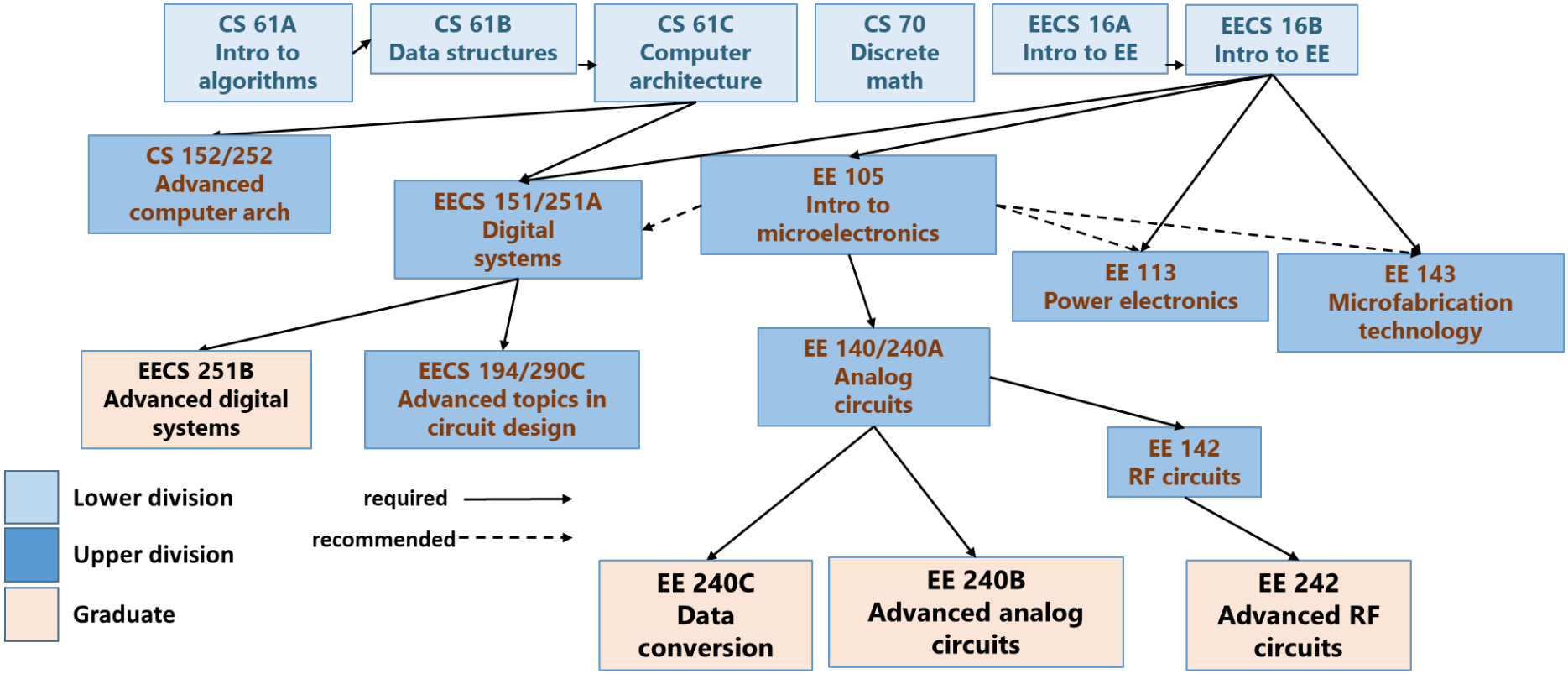
- More consolidation in the area!


AMD | XILINX

# Field has advanced!



# EECS Circuits/Computer Hardware Course Flow Map

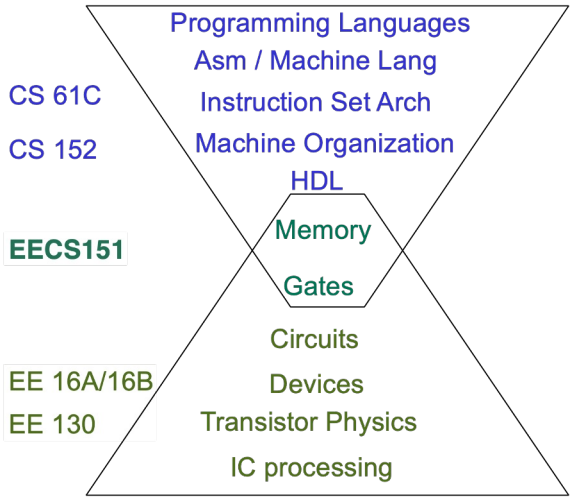


# CS152/252 – Computer Architecture and Engineering

- (More) advanced topics in computer architecture:
  - Superscalar,
  - out-of-order machines,
  - vectors,
  - GPUs,
  - multithreading,
  - memory hierarchy

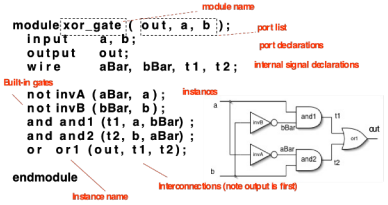
# EECS151/251A: Introduction to Digital Design and Integrated Circuits

### Bring EE and CS Together!

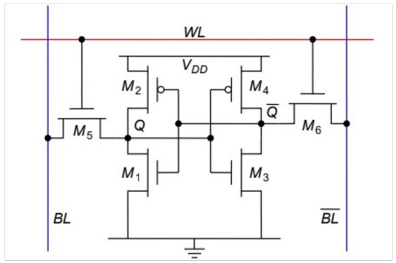



### Build Your Own Computer!

Digital Logic Design

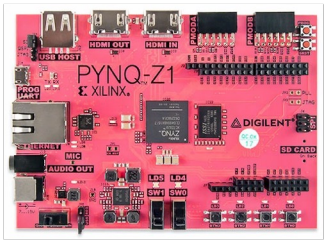



Integrated Circuits

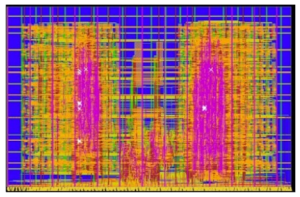



### Get Your Hands Dirty!

FPGA Labs




ASIC Labs



- Offered in both Spring and Fall semesters
- Prerequisite: 61C

# EECS251B – Advanced Digital Circuits

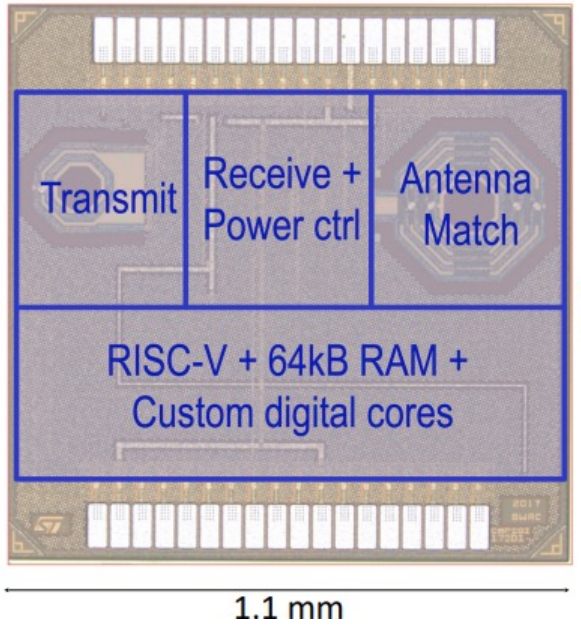
- Starts with modern SoC Design
- A deeper dive into technology, devices and models
- Variability and a case study of large SRAM arrays
- Most of the class is low-power design and power management
- ASIC projects

# EE290C/CS294 – Advanced Topics Classes

- Targeting graduate students
- But often advanced undergrads can take them as well
- EE290-2: Hardware for Machine Learning, Spring 2021
  - Instructor: Sophia Shao
    - https://inst.eecs.berkeley.edu/~ee290-2/
  - Goals:
    - What is **hardware for machine learning**?
    - What are the **technical challenges** we need to solve?
    - What **research infrastructure** is needed to enable studies?
    - What **new opportunities** can we unlock for the future ML hardware?
  - Invited guest lectures from Google, Facebook, Microsoft, MLPerf, and more…

# EECS194/290C: The Tapeout Class!

- Design a complete system on a chip
  - Microprocessor + memory
  - 2.4 GHz radio
  - Analog support (ADC, bandgap, temp sens
- "Tape out" – send it for fabrication at T
- Real-world experience
  - Fight with your friends over interfaces, rea
  - "Mostly correct" doesn't cut it
- + The Bring-up Class in Fall



# Digital Systems/Computer Architecture Research

- Exploring new areas by using high productivity design
- Research opportunities in:
  - High-performance microprocessor design
  - Domain-specific architectures
    - Machine learning and emerging applications
  - Hardware-software co-design
    - Improved performance and efficiency
  - High-productive hardware design and verification
    - Tools to improve the productivity of hardware designers

# Time to become a modern Renaissance Person

- Modern hardware designers need to understand more than just hardware.
  - Driving applications, e.g., ML
  - Compiler
  - Operating system
  - Computer architecture
  - Digital/Analog circuit design
  - Devices
- Willing to break abstractions.
  - Time for vertically integrated ideas!

Getty Images

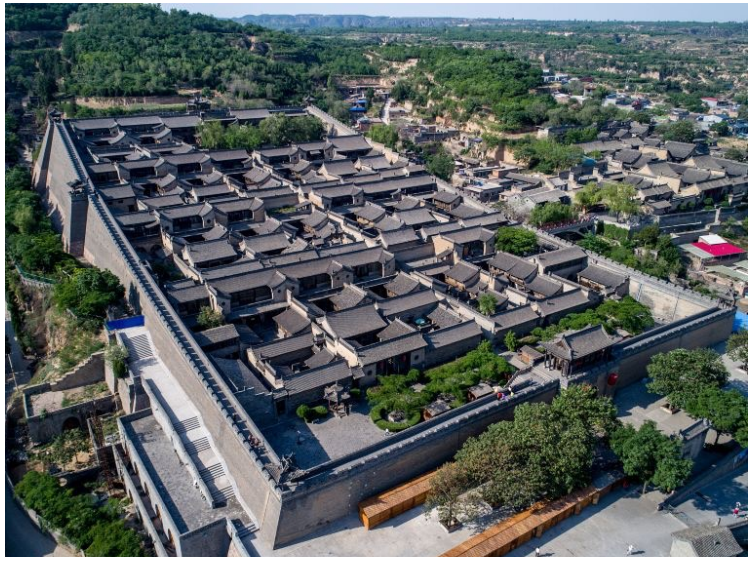
# Architecture is a reflection of time.

- Computing system evolves with the demand of applications and the behaviors of underlying technologies.
- Be brave: build hardware that reflects your time!
- "*A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die and a new generation grows up that is familiar with it*." Max Planck

*By Benh LIEU SONG (Flickr) - Louvre Courtyard, Looking West, CC BY-SA 4.0*

# Architecture is a conversation with space.

- Computing system also becomes increasingly spatially-distributed.
  - From Skyscrapers to Hutongs
- Be considerate: understand your neighbors as yourself.
- "*If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained you will also suffer a defeat. If you know neither the enemy nor yourself, you will succumb in every battle*." Sun Tzu, The Art of War.



*Wang Family Compound*

# CS152/CS252A Spring 2023 Staff Team

Animesh Agrawal

Head TA

Abraham Gonzalez

TA

Allison Husain

TA

Divija Hasteer

TA

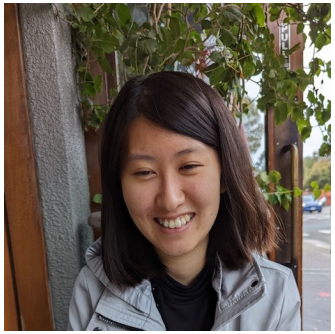
Professor Sophia Shao

Alex Hao

Reader

Edwin Lim

TA



Jamie Hong

TA


Prashanth Ganesh

TA

# Thanks to all of you!

- It's a challenging course.
  - Worked nearly as hard as you did ☺
  - Thanks all of you for working with us to put this course together!
- We still had a lot of fun!
- Hope you had too!
- Stay Curious. Stay Optimistic!