CS/SE 2340 - Computer Architecture

01 Introduction to Computer Architecture

Dr. Alice Wang

Person 1: Do you know how to use Outlook?
Person 2: As a matter of fact, I Excel at it.
Person 1: Was that a Microsoft Office pun?
Person 2: Word.

Agenda

- Welcome!
- Introduction to Computer Architecture
- Computer Organization

Please feel free to stop me anytime for questions

Instructor Intro:

Dr. Alice Wang
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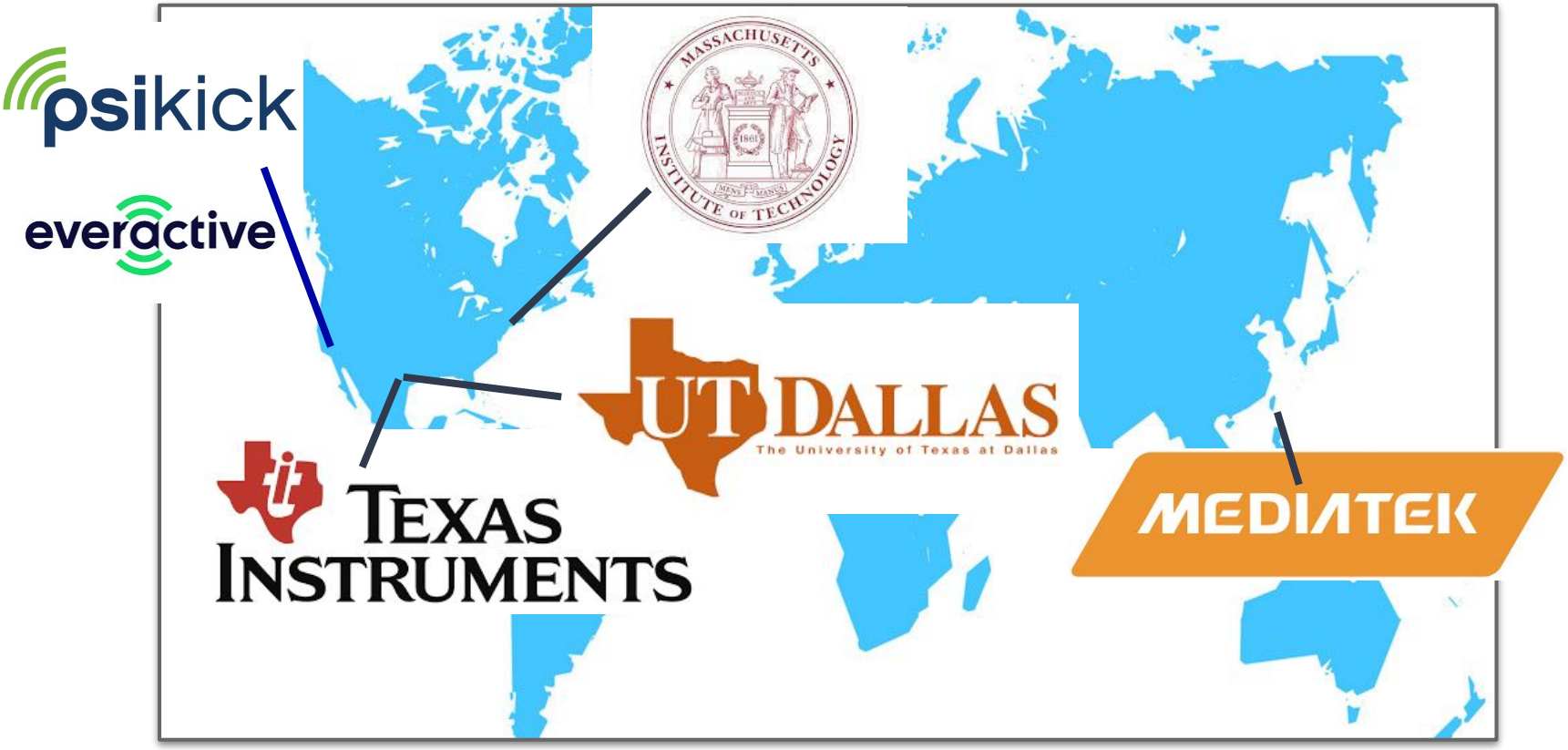
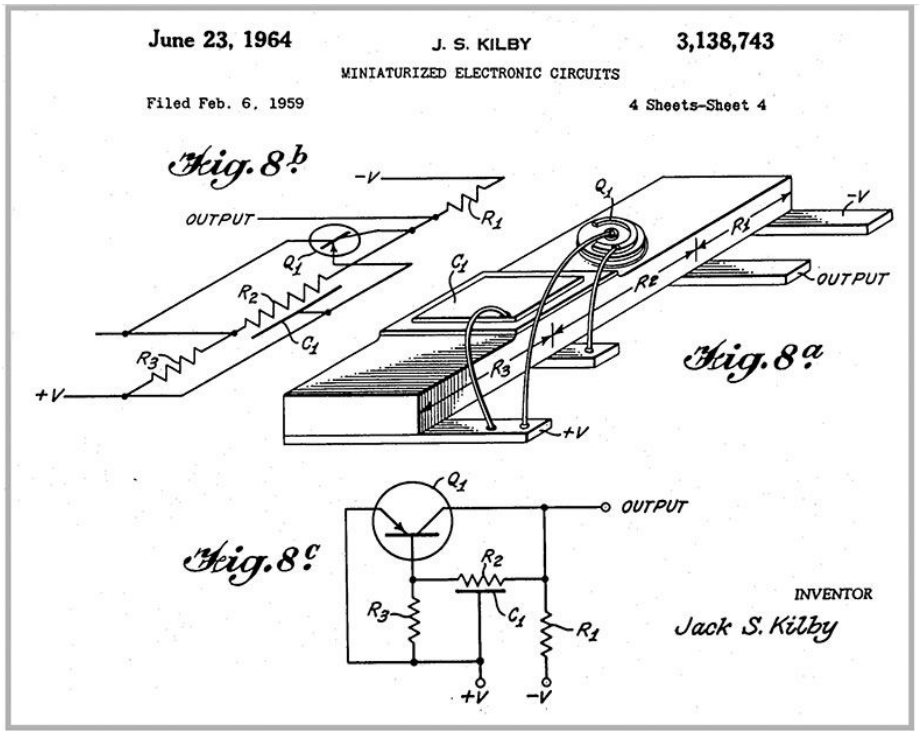


Integrated Circuit invented close by!



- Jack Kilby from Geophysical Science Incorporated (GSI) invented the first Integrated Circuit (IC).
- The idea moved to Silicon by Robert Noyce (Intel) starting the “Silicon Valley”
- GSI rebranded themselves to Texas Instruments (TI).
- TI founders came up with the Graduate Research Center of the Southwest (GRCSW) birth of the University of Texas at Dallas.

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What’s in a Computer?

Where can we find Computers

Personal computer

Data server

IBM Watson

Where can we find Computers

Smartphone

Smart devices

Wearables

Smart homes

Where can we find Computers

Cars/Vehicles

Medical devices

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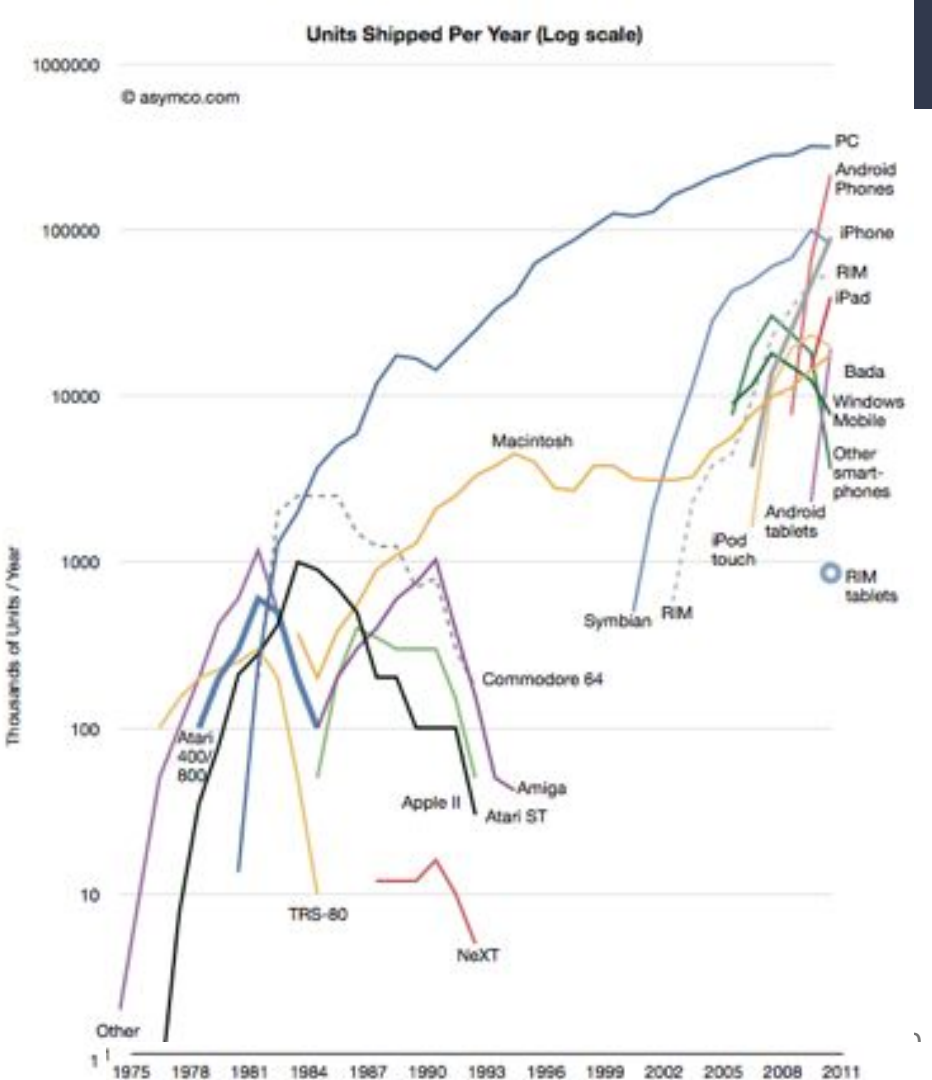
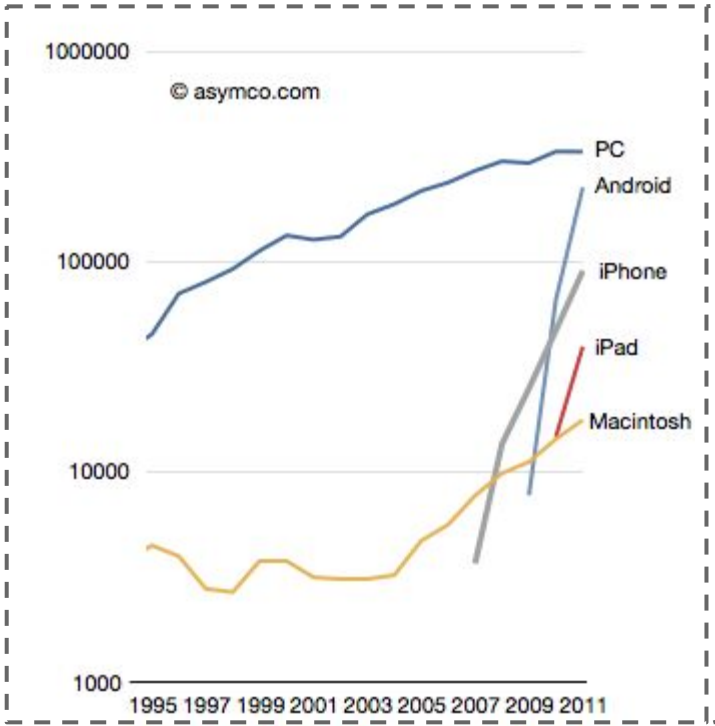
The PC Era

PC’s drove semiconductor shipments for 30+ years

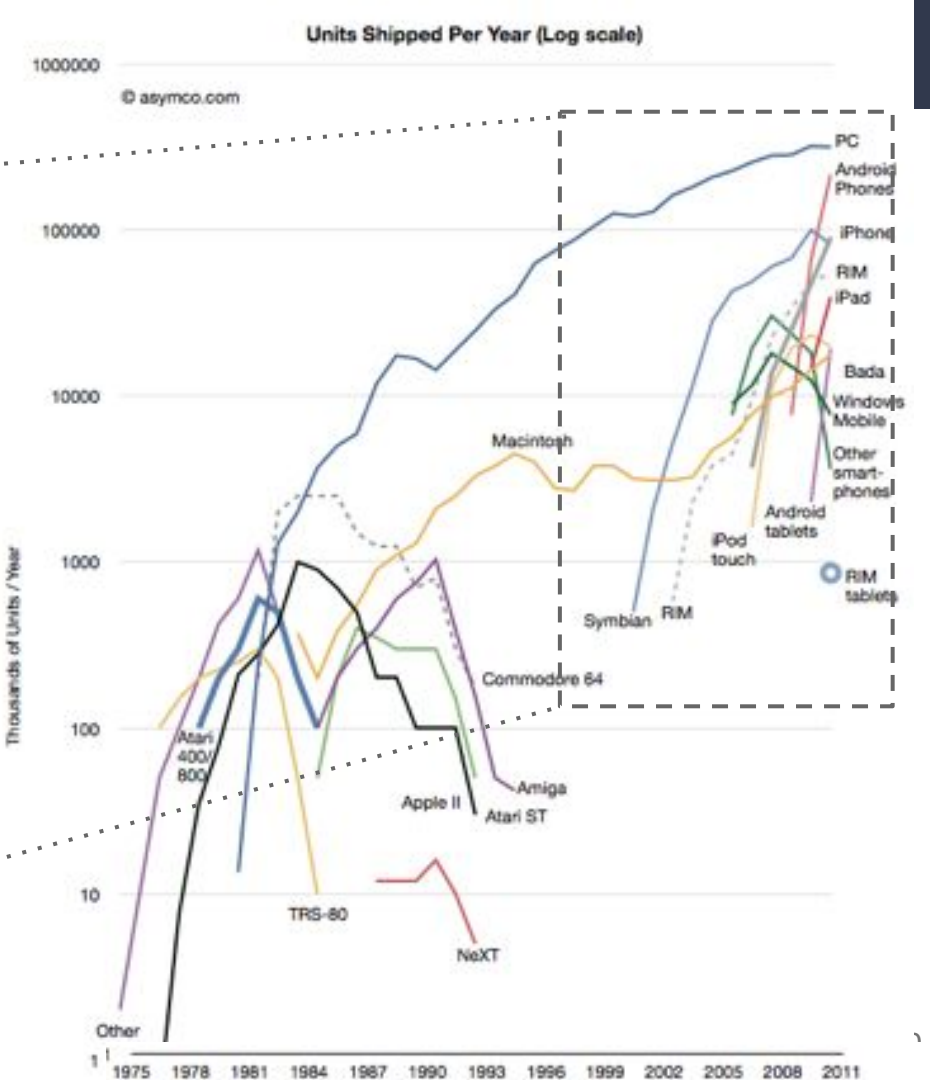


[Link to article]

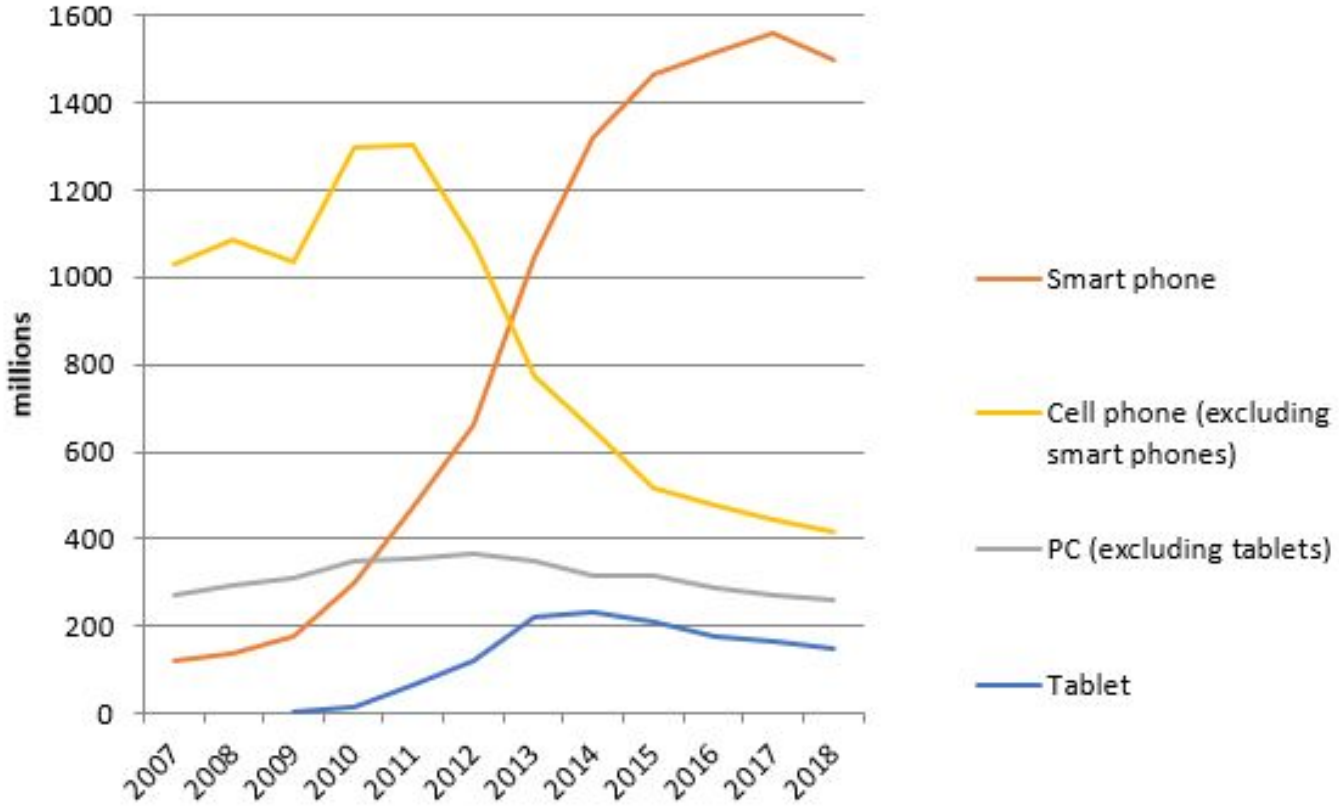
The PC Era



PC's overtaken near 2012



The PostPC Era → Smartphones



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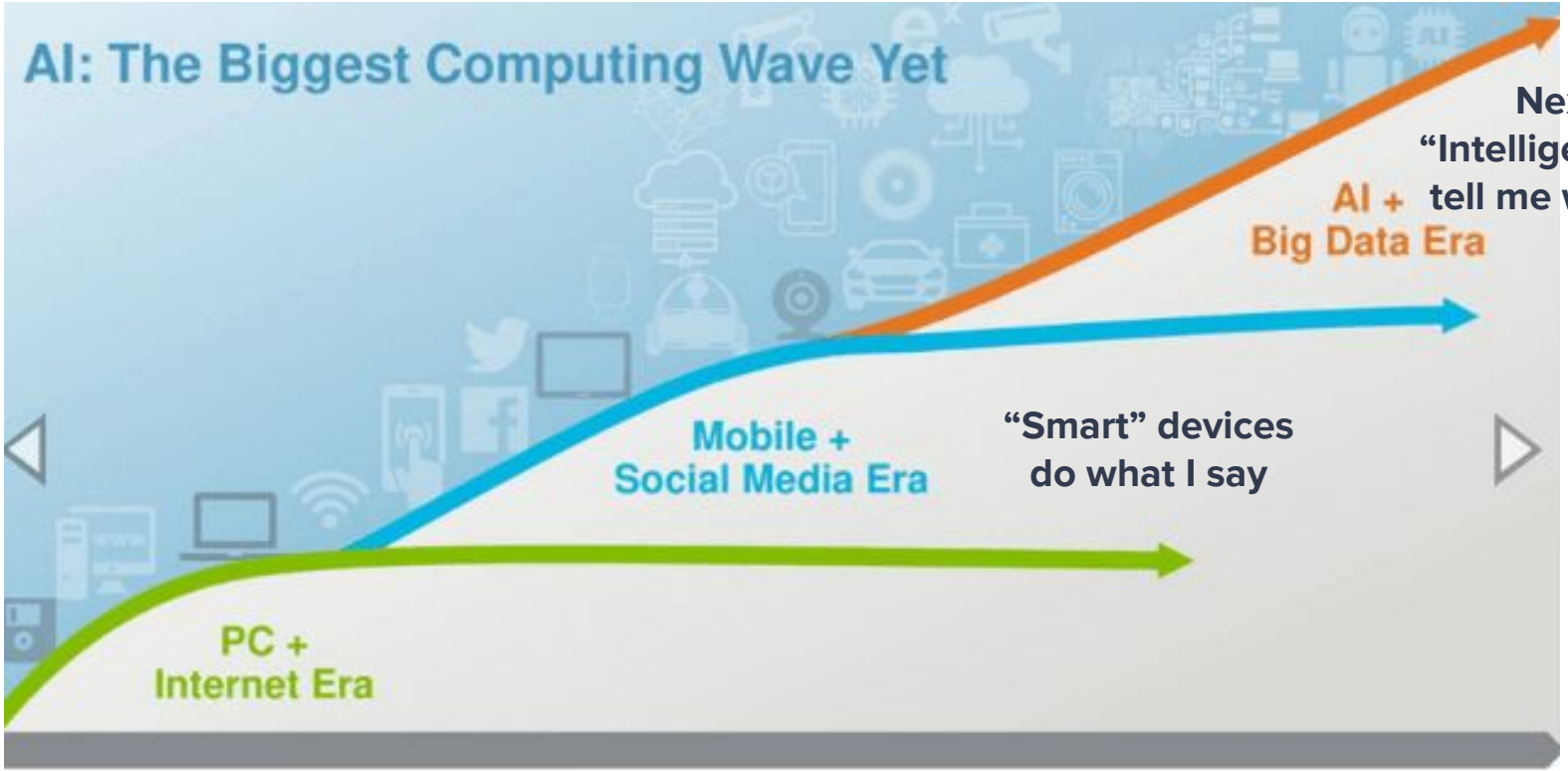
What's the next driver?



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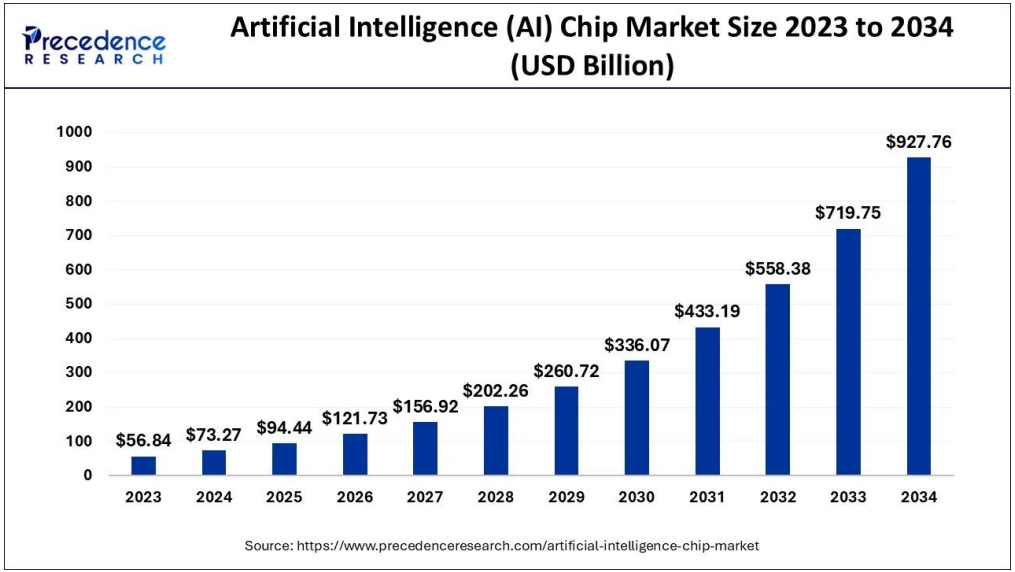
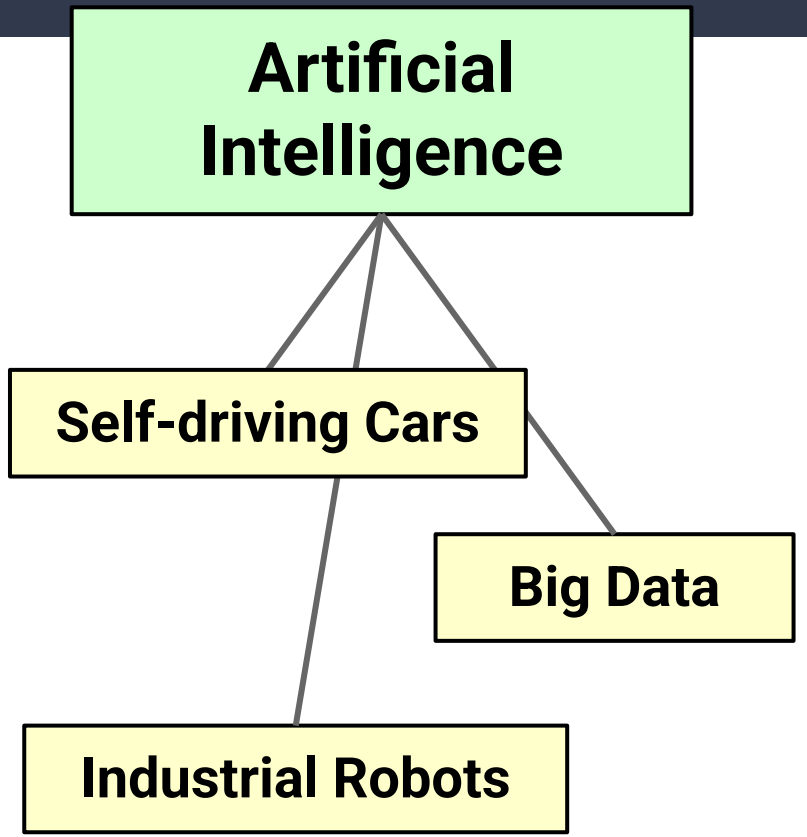
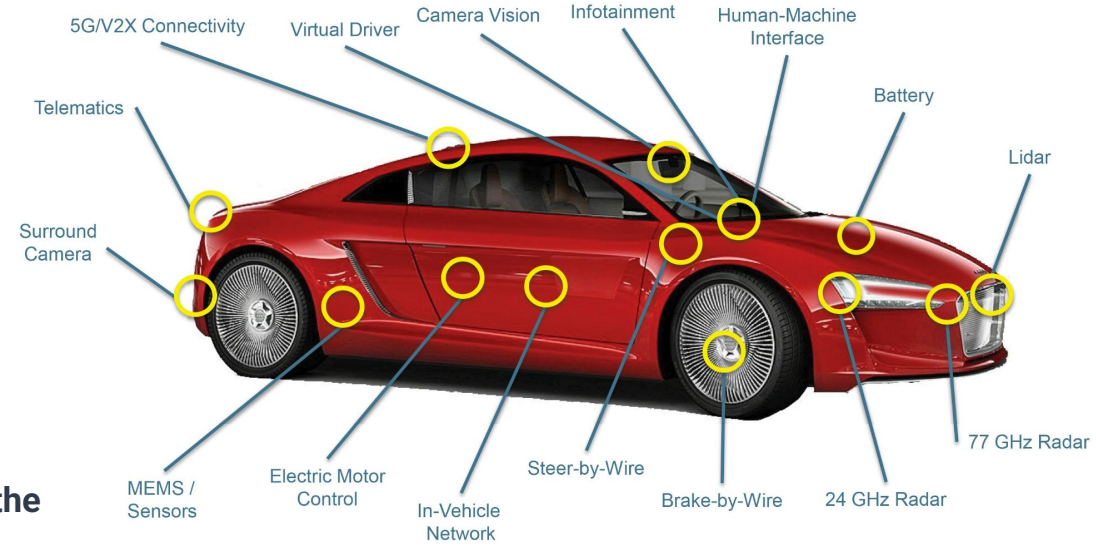
AI applications



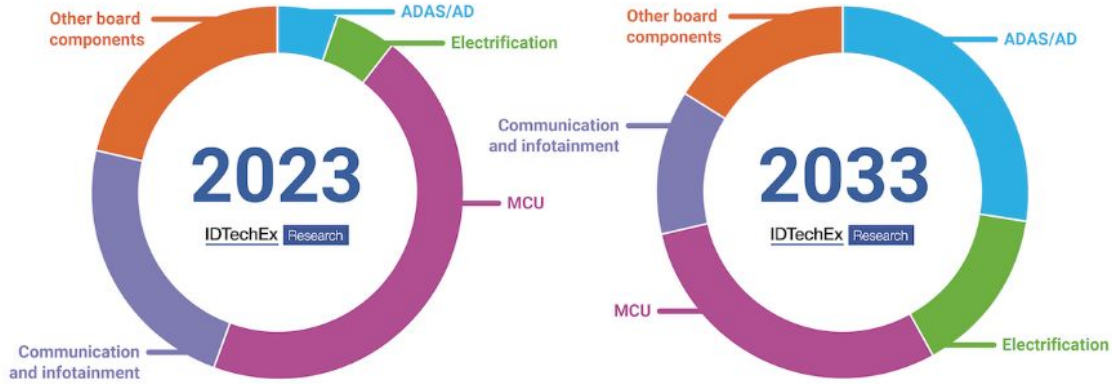
What is the Compound Annual Growth Rate (CAGR)?



Self-driving cars



Semiconductor Distribution in the Average Car



ADAS = Advanced Driver Assisted System
AD = Autonomous Driving

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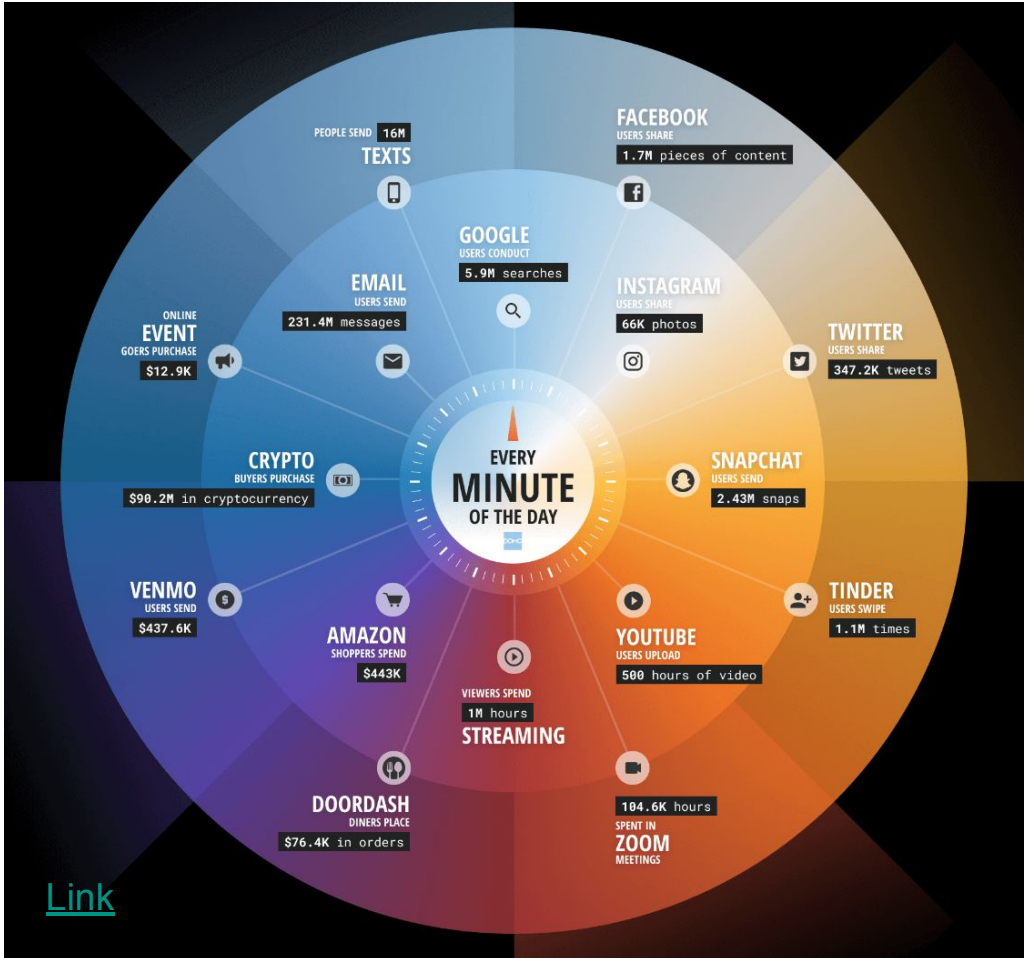
Big Data / Computing



Link

What makes it Big?

3V's: Greater variety of data, arriving in increasing volumes and with more velocity

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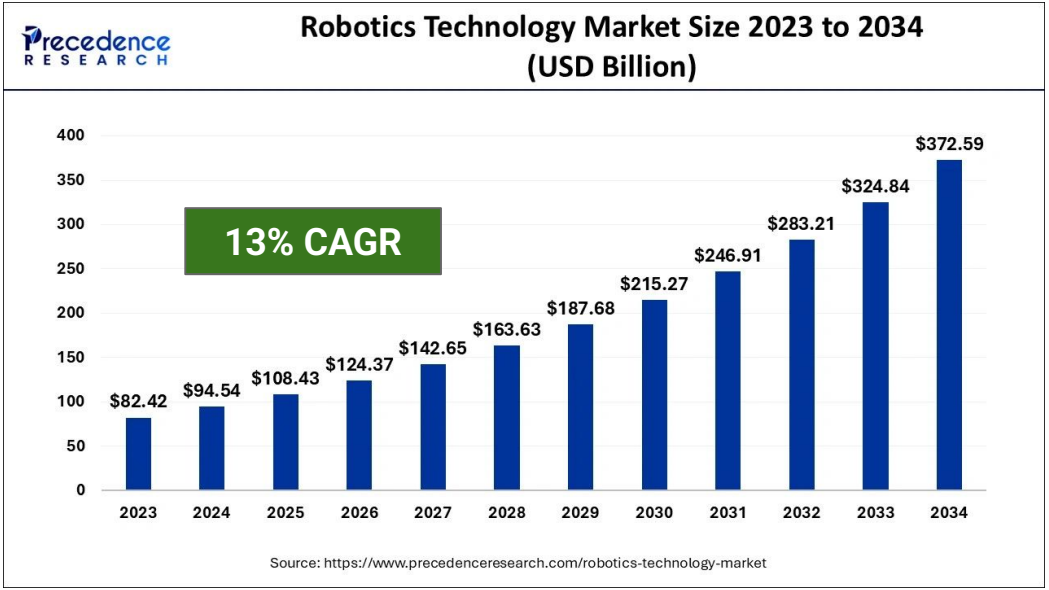
Robotics



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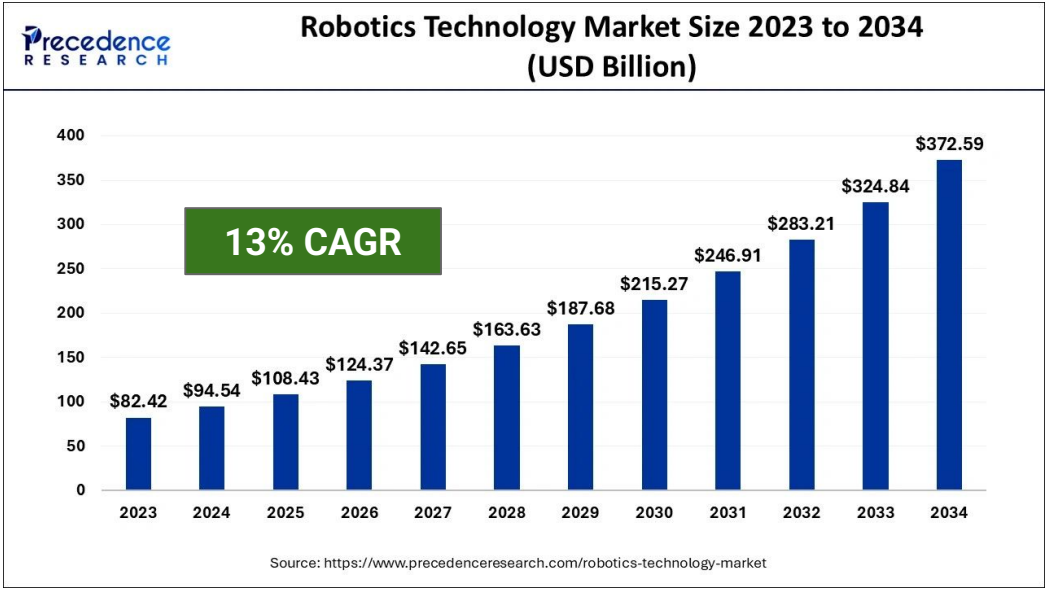
Robotics



Not a rumor - J595 expected in 2026-27

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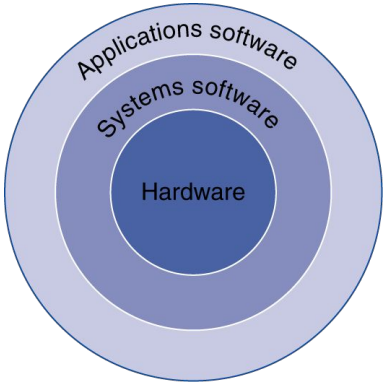
How is your Computer organized

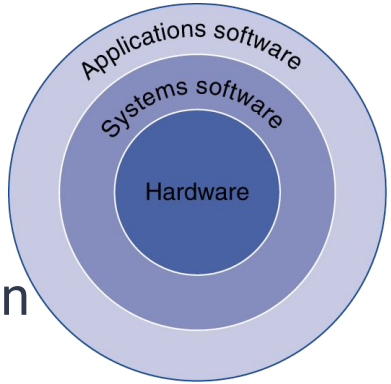
- Application software
  - Written in High-Level Language (HLL)
  - Software that is used directly by end-users (that's us!)



What are common examples of Application Software?

How is your Computer organized

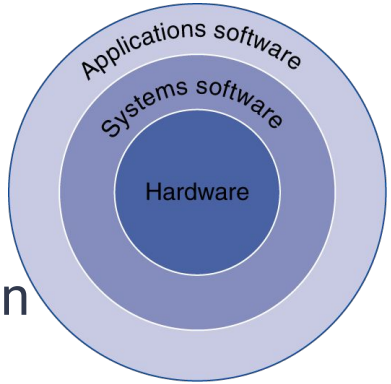
- Application software
  - Written in High-Level Language (HLL)
- System software
  - Makes sure the application software can be run on the hardware



What are common examples of System Software?

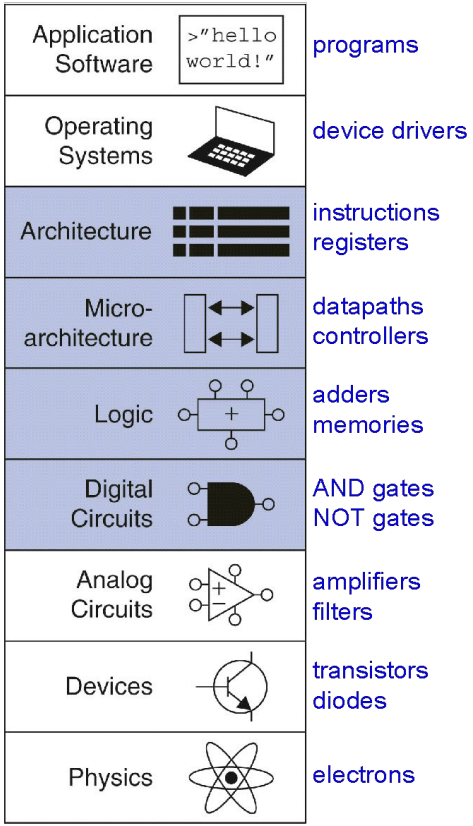
How is your Computer organized

- Application software
  - Written in High-Level Language (HLL)
- System software
  - Makes sure the application software can be run on the hardware
- Hardware
  - Processor, memory, I/O controllers



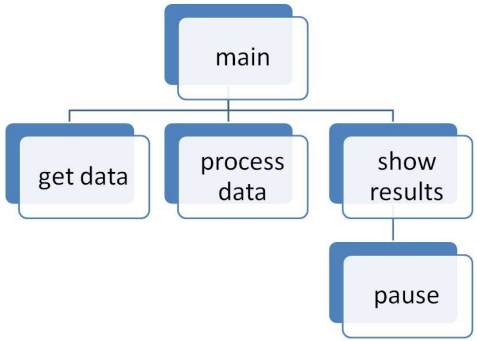
CS/SE 2340

Beauty of Abstraction

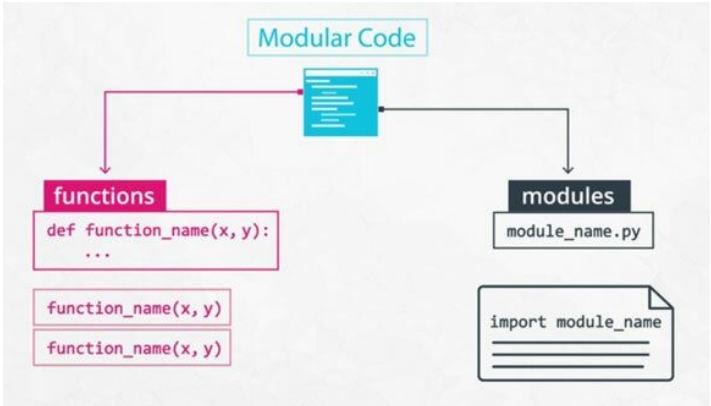


- Abstraction is the process of simplifying complex systems or concepts by hiding unnecessary details and focusing on relevant aspects
- Many benefits of abstraction
  - Shielding from lower levels
  - Protect engineering investment

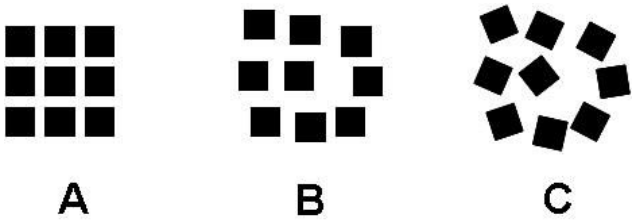
What makes Good Abstraction?



1. Hierarchy: System divided into manageable levels

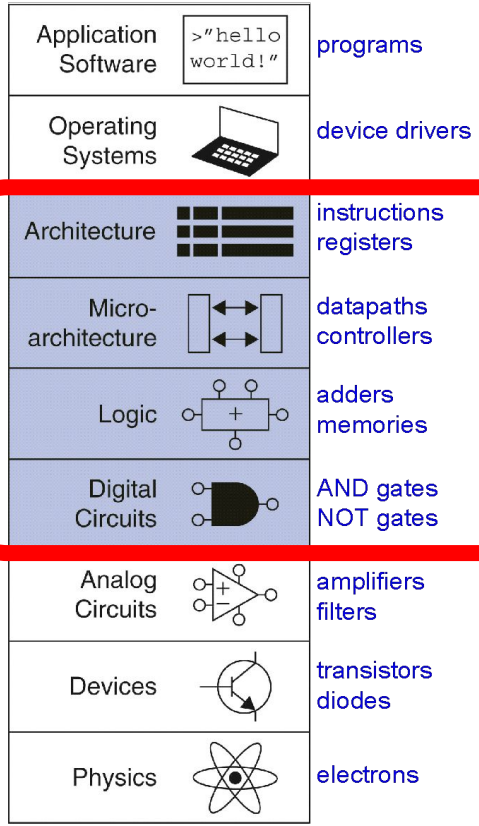


2. Modularity: Having well-defined functions, modules and interfaces

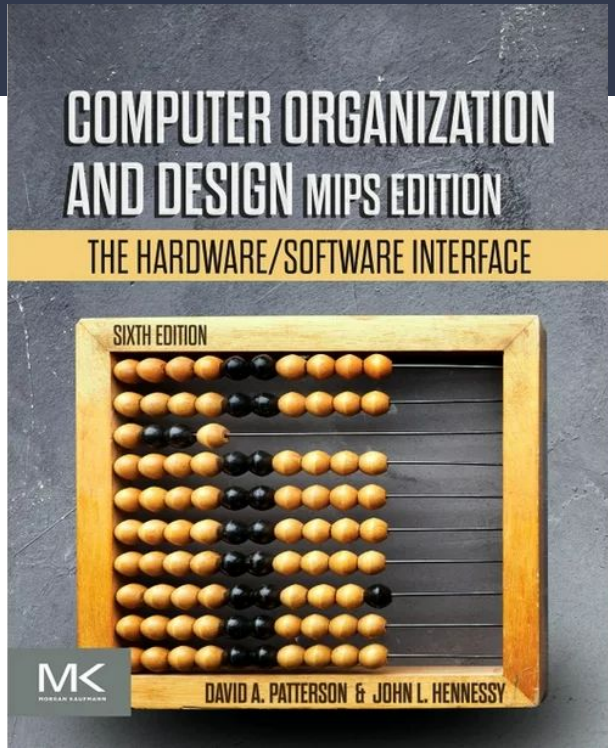


3. Regularity: Capture recurring patterns, promotes uniformity, so modules are easily reused

Where is CS/SE 2340?



Focus of this course



Required Textbook: “Computer Organization and Design - The Hardware/Software Interface – 6th Edition”, Patterson and Hennessey, Morgan-Kaufmann

Note: there are several editions of the same title, make sure that you get the correct edition (for MIPS).

Below Your Program

	Level	Readability	Code-type	Examples
High-level code	High-level	Human-readable	Machine-Independent	C, Java, Python
Assembly code	Low-level	Human-readable	Machine-dependent	ARM, MIPS, x86
Machine code	Lowest-level	Machine-readable	Machine-dependent	0’s and 1’s

Coding Example

High-level

```
int f, g, y;  // global



int main(void)
{
  f = 2;
  g = 3;

  y = sum(f, g);
  return y;
}

int sum(int a, int b) {
  return (a + b);
}
```

Assembly code

```
.data
f:
g:
y:
.text
main:
  addi $sp, $sp, -4    # stack frame
  sw   $ra, 0($sp)     # store $ra
  addi $a0, $0, 2      # $a0 = 2
  sw   $a0, f          # f = 2
  addi $a1, $0, 3      # $a1 = 3
  sw   $a1, g          # g = 3
  jal  sum             # call sum
  sw   $v0, y          # y = sum()
  lw   $ra, 0($sp)     # restore$ra
  addi $sp, $sp, 4     # restore $sp
  jr   $ra             # return to
    OS
sum:
  add  $v0, $a0, $a1   # $v0 = a + b
  jr   $ra             # return
```

Machine coding

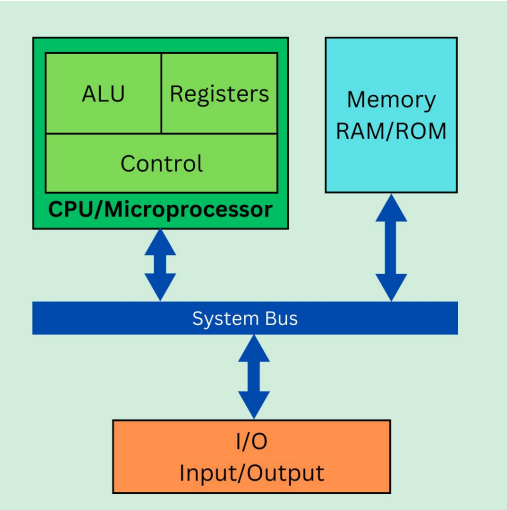
Executable file header	Text Size	Data Size
	0x34 (52 bytes)	0xC (12 bytes)

Text segment	Address	Instruction
addi $sp, $sp, -4	0x00400000	0x23BDFFFC
sw $ra, 0 ($sp)	0x00400004	0xAFBF0000
addi $a0, $0, 2	0x00400008	0x20040002
sw $a0, 0x8000 ($gp)	0x0040000C	0xAF848000
addi $a1, $0, 3	0x00400010	0x20050003
sw $a1, 0x8004 ($gp)	0x00400014	0xAF858004
jal 0x0040002C	0x00400018	0x0C10000B
sw $v0, 0x8008 ($gp)	0x0040001C	0xAF828008
lw $ra, 0 ($sp)	0x00400020	0x8FBF0000
addi $sp, $sp, -4	0x00400024	0x23BD0004
jr $ra	0x00400028	0x03E00008
add $v0, $a0, $a1	0x0040002C	0x00851020
jr $ra	0x00400030	0x03E00008

Data segment	Address	Data
	0x10000000	f
	0x10000004	g
	0x10000008	y

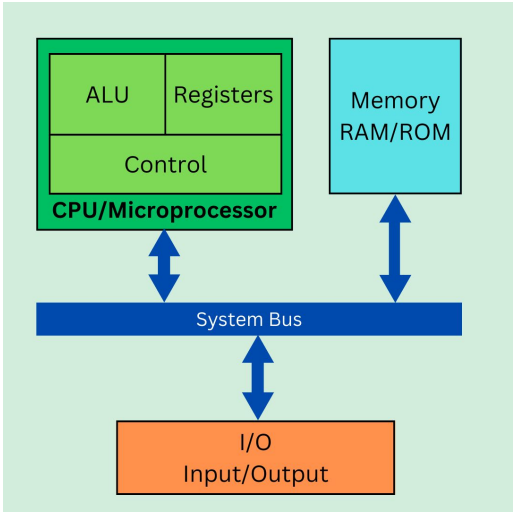
Microprocessor Terminology

- To execute a software program, the microprocessor **“reads”** each instruction from memory, **“interprets”** it, then **“performs”** it.



Microprocessor Terminology

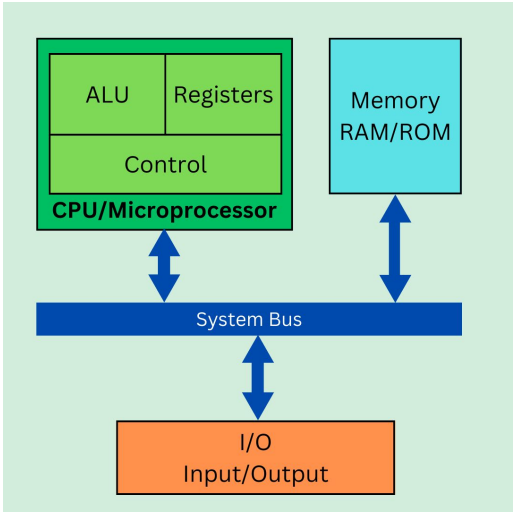
- To execute a software program, the microprocessor **“fetches”** each instruction from memory, **“decodes”** it, then **“executes”** it.



Microprocessor Terminology

- To execute a software program, the microprocessor **“fetches”** each instruction from memory, **“decodes”** it, then **“executes”** it.

Secret decoder ring



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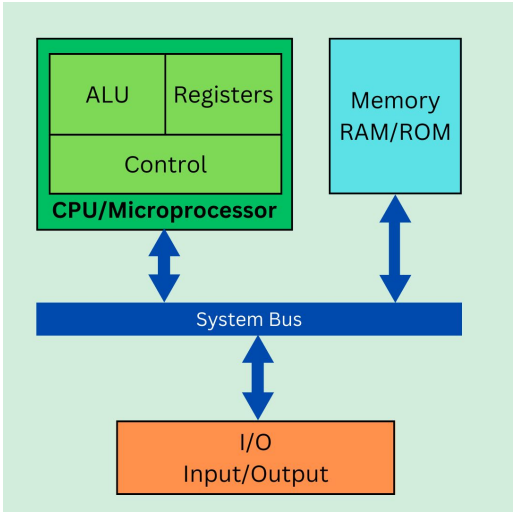

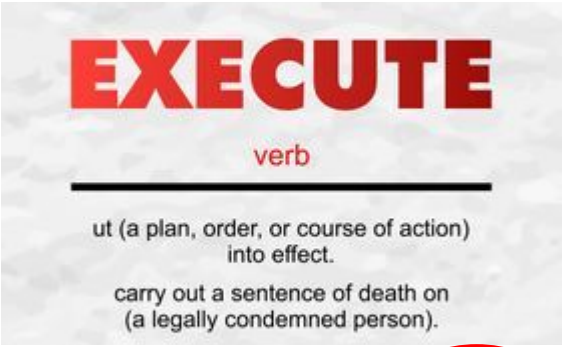

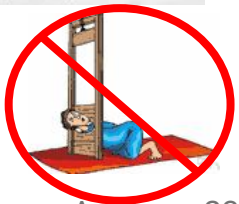

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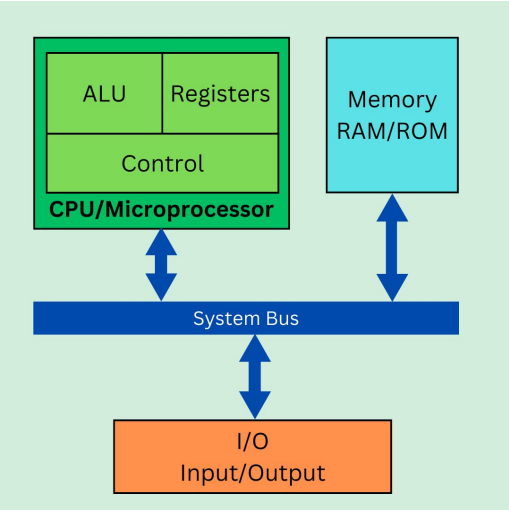
Microprocessor (CPU) Architecture

ALU = Arithmetic (add, subtract) Logic (AND, OR) Unit

Registers = Stores data during the execution of the program

Control = Timing and data flow within the CPU and between CPU and other blocks



System Bus: Group of wires to communicate between CPU and other blocks

Memory: Stores information like data and instructions

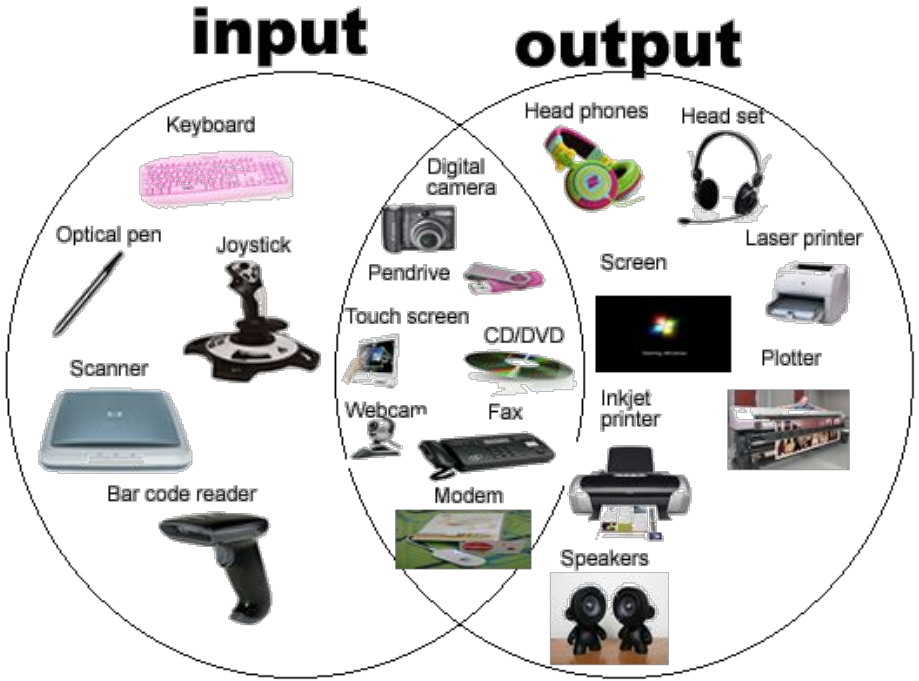
Input/Output (I/O): Communicates w/ outside world

Same components for all kinds of computer

What are some common I/O to a computer?

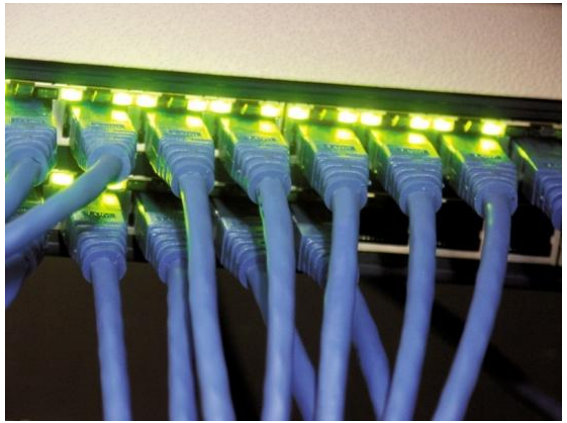
Hard I/O

Data is transferred between a computer and a physical device.



Soft I/O: Networks

- Data is transferred over a network
  - Local area network (LAN): Ethernet
  - Wide area network (WAN): the Internet
  - Wireless network: WiFi, Bluetooth, NFC



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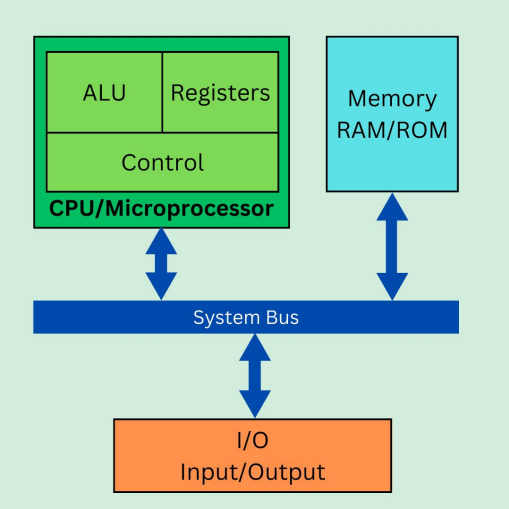

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Same components for all kinds of computer

Memory Arrays

- Efficiently stores large amounts of data
- Common types:
  - Volatile storage
    - Static random access memory (SRAM)
    - Dynamic random access memory (DRAM)
    - Read only memory (ROM)
  - Non-volatile storage
    - Flash
    - Hard-disk drives

You can never have enough memory!

Volatile vs Non-volatile Memories

vol·a·tile

/ˈväləd(ə)l/

adjective

adjective: **volatile**

1. ~~(of a substance) easily evaporated at normal temperatures.~~
   "volatile solvents such as petroleum ether, hexane, and benzene"

   Similar: evaporative | vaporous | vaporescent | explosive | eruptive

2. ~~liable to change rapidly and unpredictably, especially for the worse.~~
   "the political situation was becoming more volatile"

   Similar: tense | strained | fraught | uneasy | uncomfortable | charged

   - (of a person) liable to display rapid changes of emotion.
     "a passionate, volatile young man"

     Similar: unpredictable | changeable | variable | inconstant | inconsistent

3. (of a computer's memory) retaining data only as long as there is a power supply connected.

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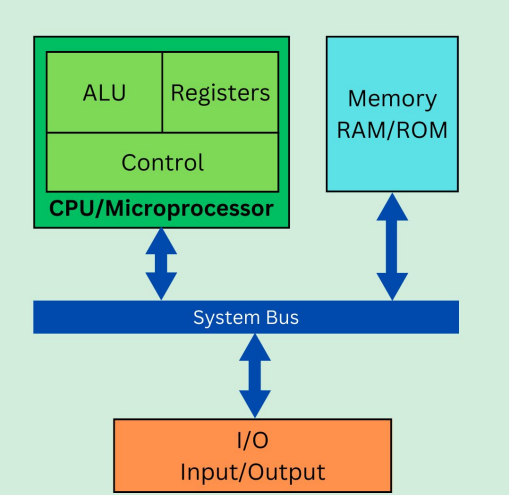

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Same components for all kinds of computers

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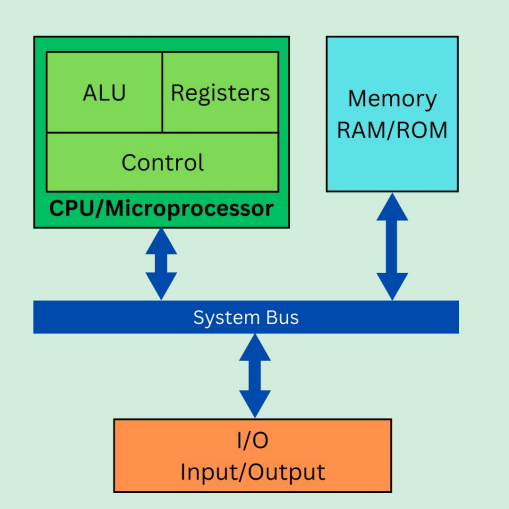


System Bus: Group of wires to communicate between the CPU and other blocks

Memory: Stores information like data and instructions

Input/Output (I/O): Communicates w/ outside world

Starting from next lecture we will start with the CPU blocks

Class Logistics - Grading

Type	#
Exam 1	10%
Exam 2	25%
Exam 3	30%
Attendance	5%
Assignments	10%
Term Project	20%
Total	100%

Score	Grade
93.0 - 100	A
90.0 - 92.9	A-
87.0 - 89.9	B+
83.0 - 86.9	B
80.0 - 82.9	B-
77.0 - 79.9	C+
73.0 - 76.9	C
70.0 - 72.9	C-
67.0 - 69.9	D+
60.0 - 66.9	D
Below 60.0	F

- There will be 7 assignments, 1 term project and 3 exams
  - The assignments will include assembly coding to ramp up skills needed for the project
- For HW questions, use the class discussion board on e-Learning
- Use the Computer Science Mentoring Center (CSMC)!

Attendance quizzes

The password for the Attendance Quiz will be give at the start of class and the quiz is open for 15 min. If you miss the attendance quiz, then you will be marked absent. You don't need to get the answer right to be counted for attendance. You will need to be on the UTD wifi and have the correct IP address to access the exam.

Attendance policy: *6 unexcused absences total leads to one letter grade drop, 8 or more unexcused absences lead to a failing grade (F).*

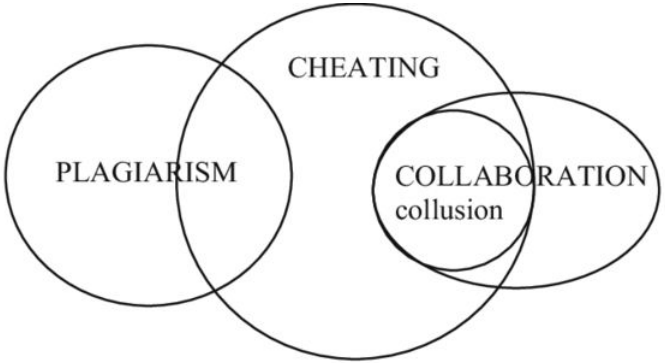
Exams @ Testing Center

- The current plan for this semester is to have three exams during the semester, two midterms at the testing center and final exam during class time in the classroom
  - Seat reservations must be made for each midterm and should be done at the beginning of the semester via this link
  - If you do not reserve your seat you will not be able to take the exam and I cannot do anything about it, so do not email me if you cannot take an exam because you failed to reserve your seat. Note: Walk-in appointments are not-allowed, no exceptions
  - Register with the testing center now because seats do fill up quickly and if you don't have a seat, I can't help you!
- There will be no makeup exams under normal circumstances.

How to study for exams

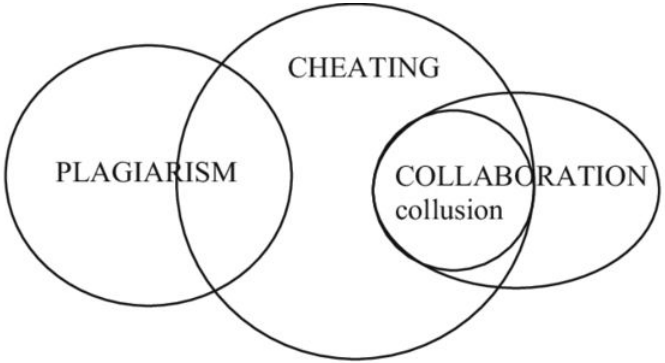
- Do the homeworks yourselves (e.g. don’t let AI do them)
- I will release a Study guide and Exam examples before each exam - you can try these problems after each lecture
- Attendance quizzes questions are also similar to those on exams

Collaboration and Plagiarism



Type	Definition	Example
Plagiarism	Copying someone else's work and passing it off as your own, without giving proper credit	Copying and pasting parts of source code from a friend without citing
Cheating	Using unauthorized sources or devices to help you achieve an outcome you wouldn't have on your own	Copying someone's answers on an assignment. Changing the comments is not enough.
Collusion	Working with others to cheat.	Sharing your assignment answers with a friend allowing them to copy it.
Collaboration	The action of working with someone to produce or create something.	Discuss assignments, share your work looking for feedback, input, or guidance. Each student needs to submit their own work.

Collaboration and Plagiarism



Type	Definition	Example
Plagiarism	Copying someone else's work and passing it off as your own, without giving proper credit	Copying and pasting parts of source code from a friend **or an LLM** without citing
Cheating	Using unauthorized sources or devices to help you achieve an outcome you wouldn't have on your own	Copying someone's answers on an assignment. **Using AI for the written portions of the assignment**
Collusion	Working with others to cheat.	Sharing your assignment answers with a friend allowing them to copy it.
Collaboration	The action of working with someone to produce or create something.	Discuss assignments, share your work looking for feedback, input, or guidance. Each student needs to submit their own work. **Using an LLM to check your answers**

MARS: MIPS RISC Assembler/Simulator

This course uses the MARS MIPS assembler and simulator.

MARS is available, free, you can download it from

- MS Teams
- eLearning

Make sure to download Java **before** you install MARS [download]

CS2340: What will you learn?

- *Knowledge and insights on computer architecture*
  - How programs are translated into the machine language
  - How the hardware executes programs
  - The hardware/software interface
  - What determines program performance
  - How hardware designers improve performance
- *Skill to program in assembly language*

Benefits from what you'll learn

- Be more employable - All large SW companies are making their own Silicon

ASIC Engineer, Design

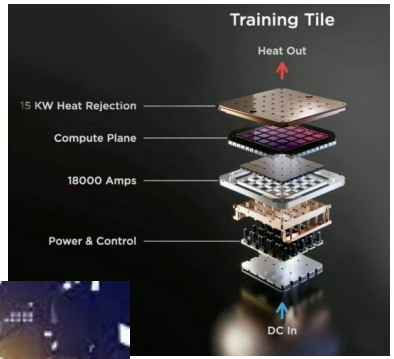
Meta · Menlo Park, CA Reposted 1 day ago · 90 applicants

$95,400/yr - $165,000/yr · Full-time

10,001+ employees · Software Development

AUTONOMOUS VEHICLES

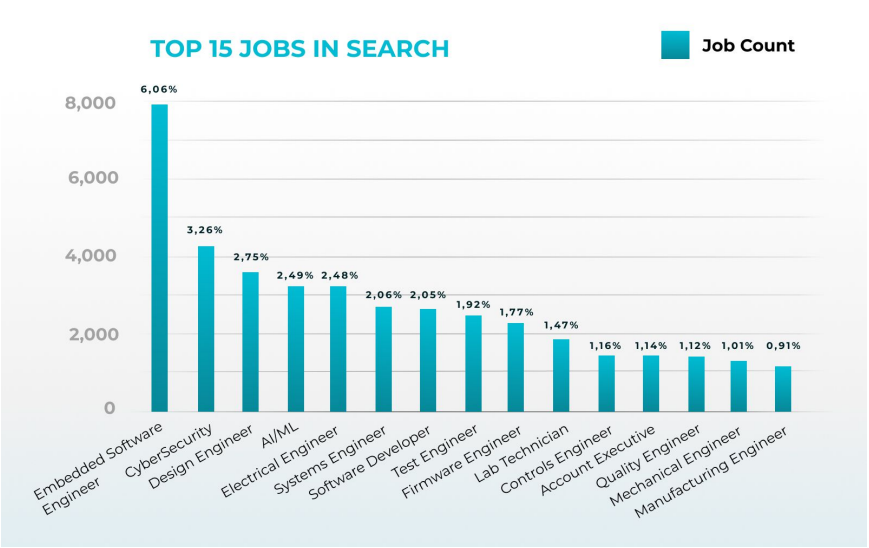
What Advantage Will Tesla Gain By Making Its Own Silicon Chips?



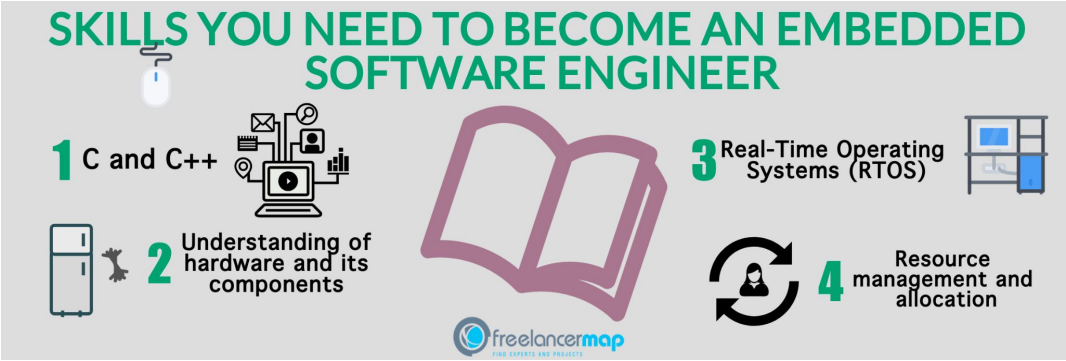
Circuit Design Engineer, Power Performance Area

Google
Sunnyvale, CA

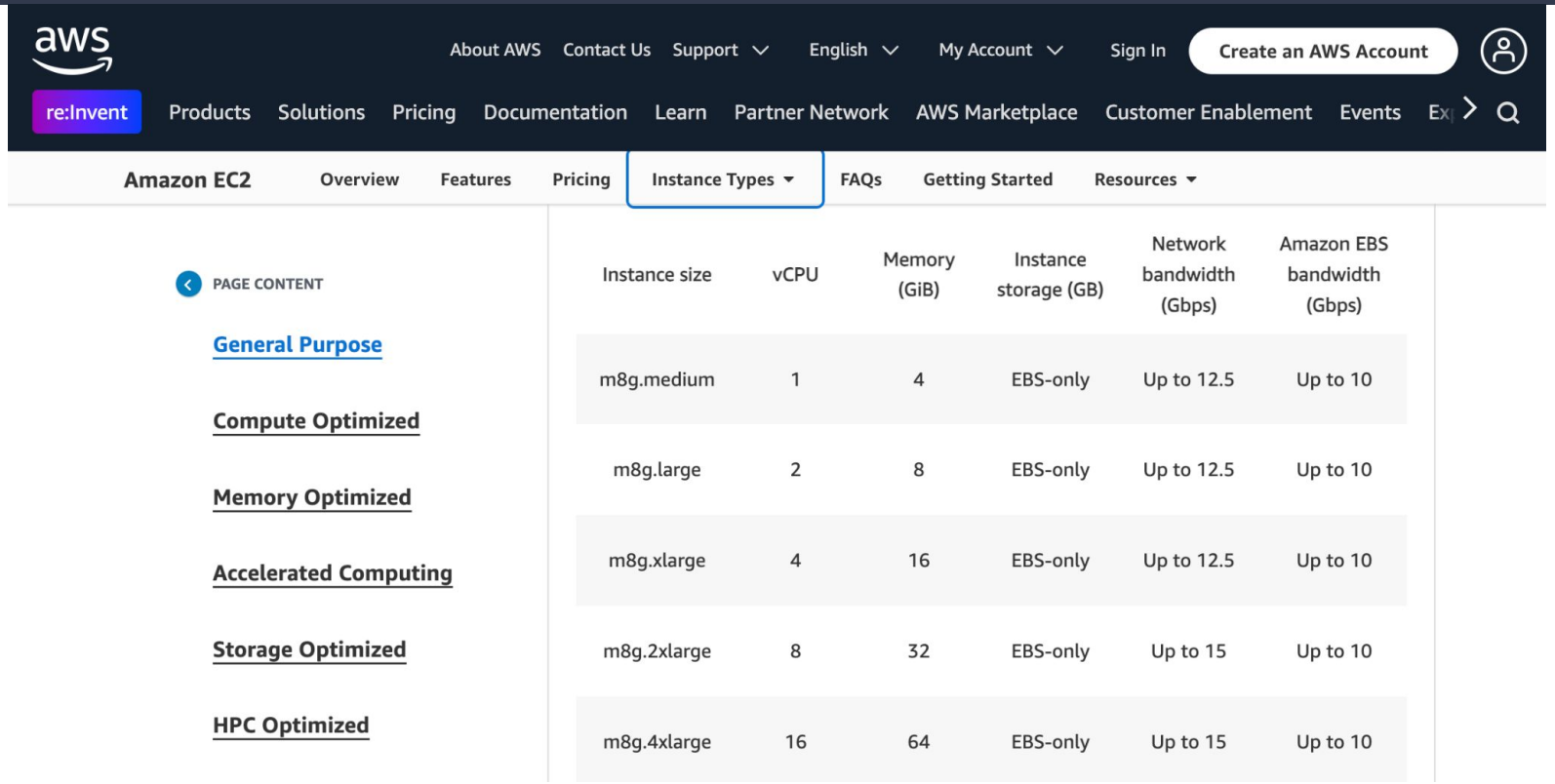
Benefits from what you'll learn



- Be a better coder - Your SW will be faster/lower-power/ more-efficient if you understand how the underlying HW works



Benefits from what you'll learn



Understand what you are purchasing when you go on AWS

Benefits from what you'll learn

Go to the Consumer Electronics Show (CES) and understand the new product announcements!

Nvidia's CEO Jensen Huang announcing RTX 5090 GPU

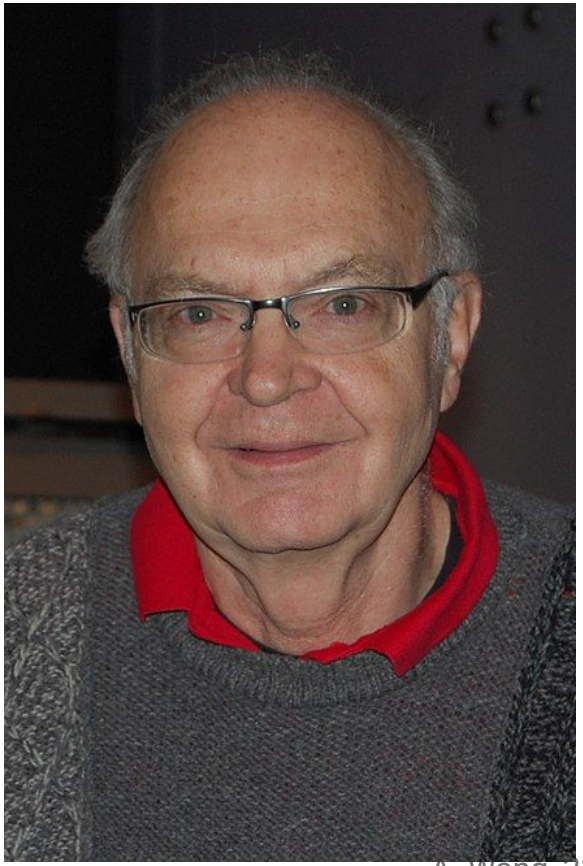
Intel and AMD announcing latest CPU's

A. Wang, 2340

And the final word from …

Donald Knuth, giant in the computer science world and author of *The Art of Computer Programming* series, put it this way:

> "People who are more than casually interested in computers should have at least *some* idea of what the underlying hardware is like. Otherwise the programs they write will be *pretty weird*."



For next lecture - Intro to Assembly Language

- Before lecture download the MARS MIPS simulator from MS Teams or eLearning
- You will need to use MARS during Lecture 2
- You will be using this simulator extensively in your HW and Project

Next lecture

Intro to Assembly Language Programming