Part 7

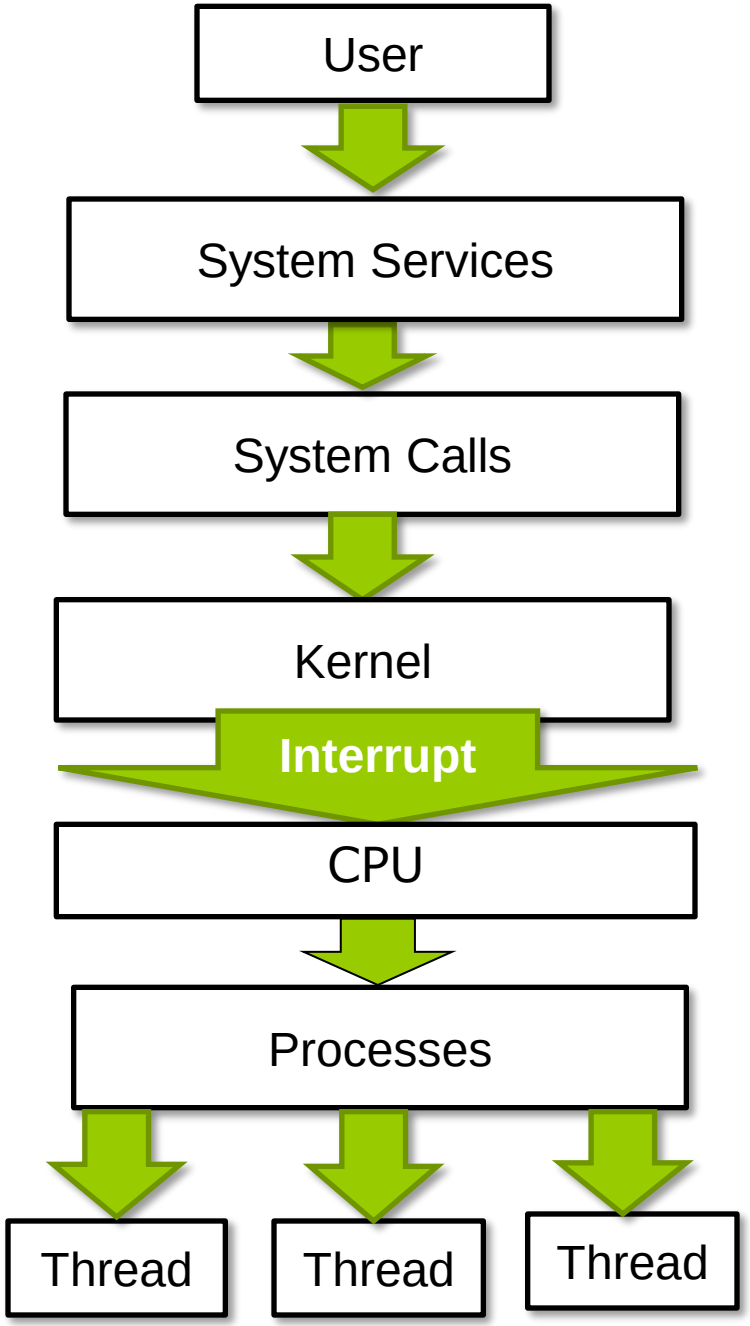
Important notes

- Please **mute** your microphone
- If you have any questions please use the **Chat feature of zoom , no microphones.**
- Please make sure zoom is showing **your full name**
- **No Recording** of my lectures
- **No make up** of Quizzes or classwork
- You need to be **in class** for quiz or classwork
- **Tests/Exams/Quizzes** answers from PPT and class notes, no outside sources.
- For **Homework and Research Paper you can** use **outside sources**

Netiquette

- Keep messages short and to the point.
- Never post a message that is in all capital letters — it comes across to the reader as SHOUTING
- Keep in mind that chat messages are meant to be constructive
- Be respectful and treat everyone as you would want to be treated yourself.
- **Be on Time**
- If you came late don’t disturb the class , join us quietly, *no need to apologize*
- I don’t read emails during the lecture
- You will be removed from zoom if you disrupt the class

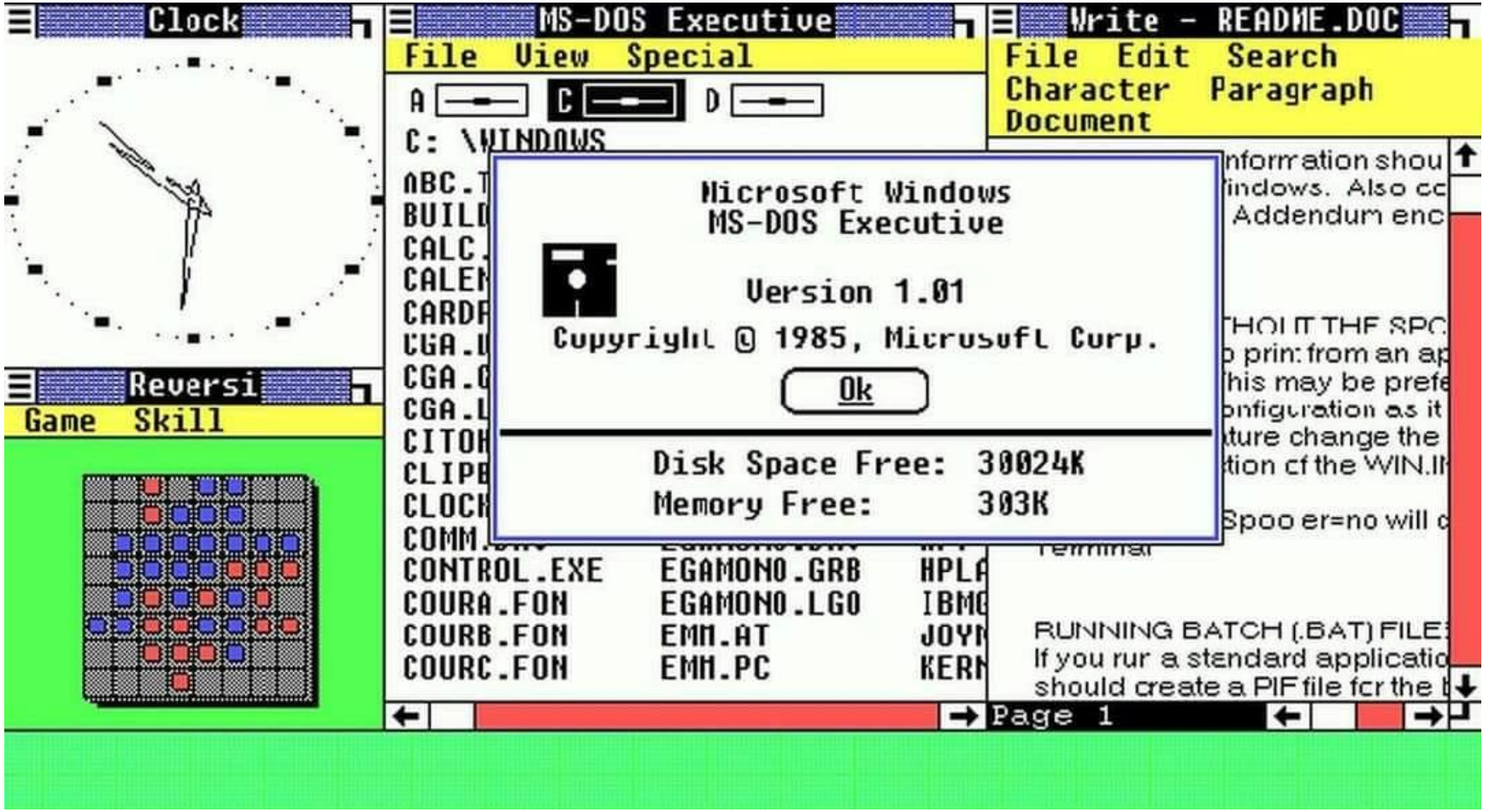
The Big Pic of OS

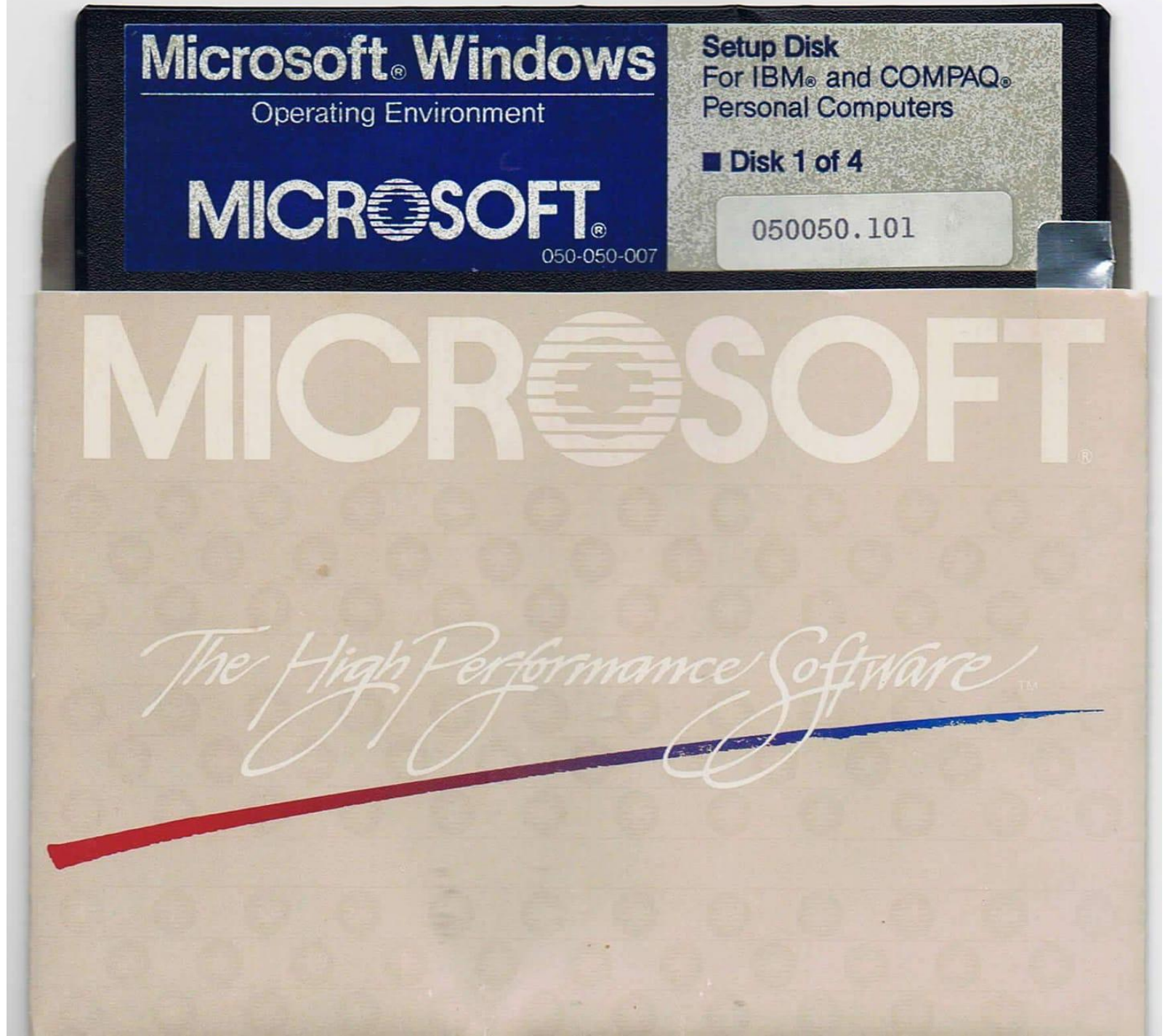


Top programming languages on GitHub

RANKED BY COUNT OF DISTINCT USERS CONTRIBUTING TO PROJECTS OF EACH LANGUAGE.

Windows 1.0 Released 20th November 1985




Microsoft® Windows
Operating Environment
MICROSOFT®
050-050-007
Setup Disk
For IBM® and COMPAQ®
Personal Computers
■ Disk 1 of 4
050050.101
MICROSOFT®
The High Performance Software™

The Central Processing Unit (CPU)


:)
Trouble-free computing since 1984.

Up to

24GB

LPDDR5 memory

Second-generation 5 nm technology

ProRes

encode and decode

6K external display support

Over

20 billion

transistors

High-performance media engine

40%

Faster Neural Engine

Industry-leading performance per watt

50%

More memory bandwidth

Up to

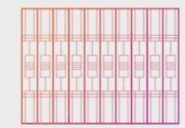
15.8 trillion

operations per second

16-core Neural Engine

8-core

CPU



Up to

10-core

GPU

18%

Faster CPU

35%

Faster GPU

100GB/s

Memory bandwidth

Thunderbolt 4

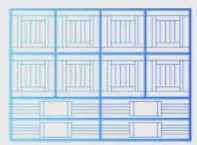
Up to
20%
faster CPU

Up to
30%
faster GPU

Industry-leading performance per watt

Up to
32GB
LPDDR5 memory

Over
40 billion
transistors



12-core
CPU

Up to
19-core
GPU

16-core
Neural Engine
15.8 trillion ops/s

40%
Faster Neural Engine

High-performance media engine with ProRes

Second-generation
5 nm technology

200GB/s
Memory bandwidth

Thunderbolt 4

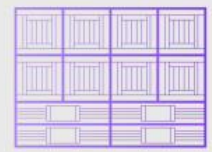
Up to
20%
faster CPU

Up to
30%
faster GPU

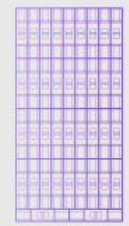
Industry-leading performance per watt

Up to
96GB
LPDDR5 memory

Over
67 billion
transistors



12-core
CPU



Up to
38-core
GPU

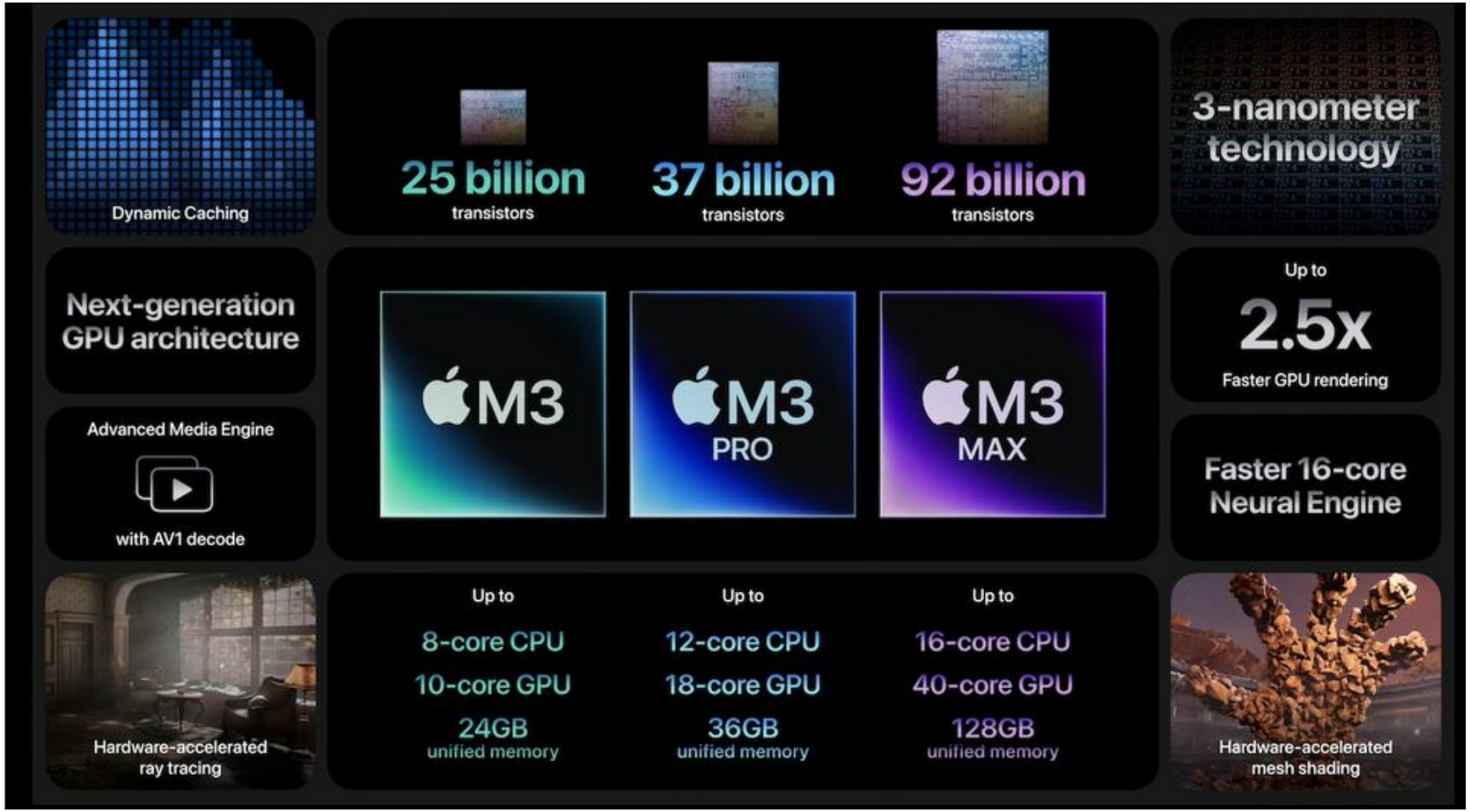
16-core
Neural Engine
15.8 trillion ops/s

40%
Faster Neural Engine

400GB/s
Memory bandwidth

High-performance media engine with ProRes

Second-generation
5 nm technology


Dynamic Caching
25 billion
transistors
37 billion
transistors
92 billion
transistors
3-nanometer technology
Next-generation GPU architecture
M3
M3 PRO
M3 MAX
Up to
2.5x
Faster GPU rendering
Advanced Media Engine
with AV1 decode
Faster 16-core Neural Engine
Hardware-accelerated ray tracing
Up to
8-core CPU
10-core GPU
24GB
unified memory
Up to
12-core CPU
18-core GPU
36GB
unified memory
Up to
16-core CPU
40-core GPU
128GB
unified memory
Hardware-accelerated mesh shading


120GB/s
Unified memory bandwidth
Tandem OLED display engine
Dynamic Caching
Up to
10-core
CPU
10-core
GPU
Hardware-accelerated mesh shading
M4
Hardware-accelerated ray tracing
Up to
50%
faster CPU than M2
Up to
4x
faster GPU than M2
ProRes
AV1
Over
28 billion transistors
Second-generation
3 nm technology
Neural Engine with
38 trillion ops/sec

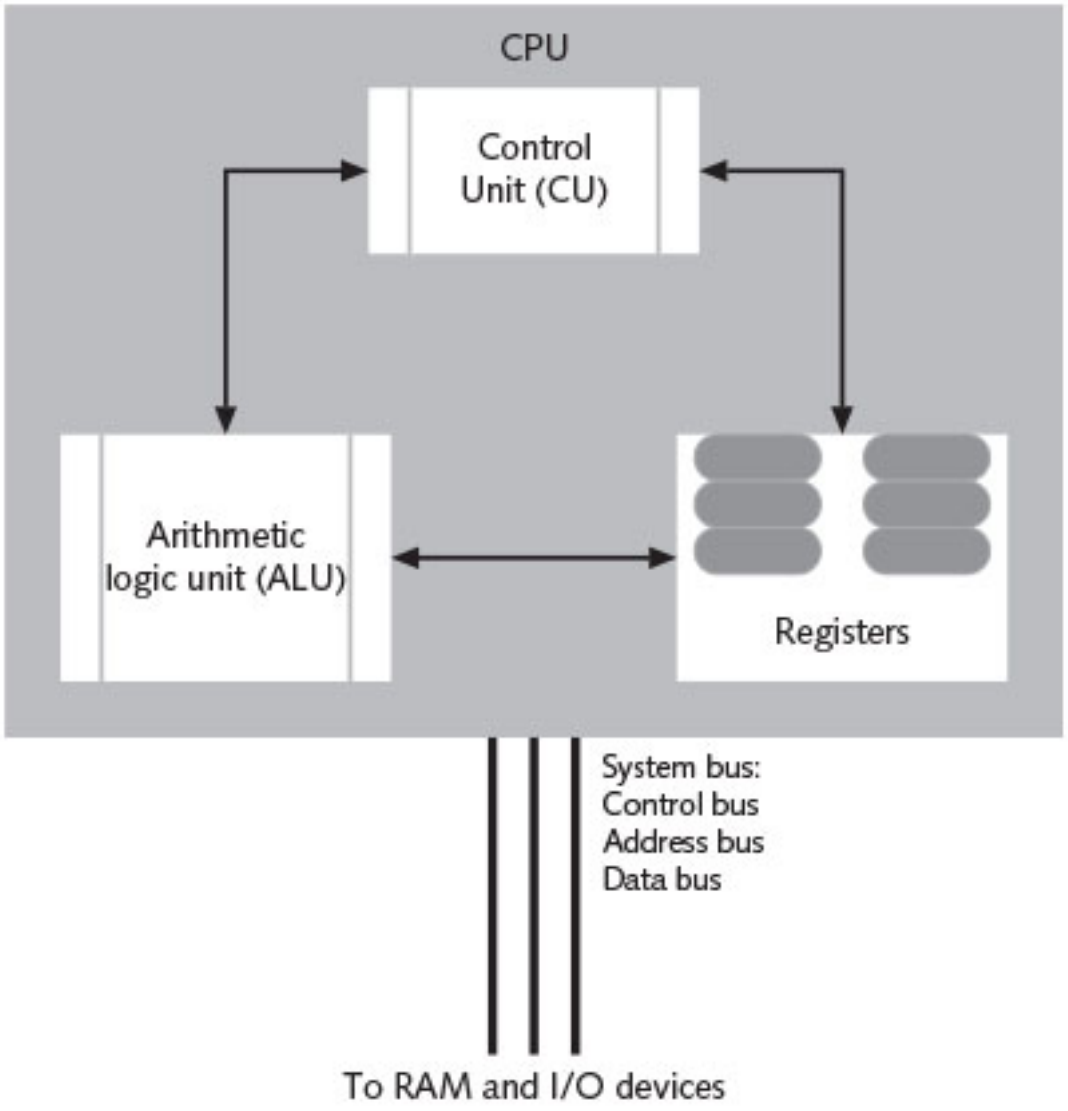
Understanding CPUs

- The **system architecture** of the computer is built **around** the CPU
  - Includes the number and type of CPUs in the hardware, and the communications routes (buses) between CPUs and other hardware components
- **CPU** – chip that performs the actual computational and logic work
- **Core** – section of the processor that actually does the **reading and execution of instructions**
  - Multicore processor has two or more cores
- **Multiprocessor computers** have multiple physical CPU chips

Basic CPU Architecture

- Most CPUs are composed of the following elements:
  - **Control unit** – provides timing and coordination between other parts of the CPU
  - **Arithmetic logic unit (ALU)** – performs the primary task of executing instructions
  - **Register** – temporary holding location where data must be placed before the CPU can use it
  - **System bus** – series of lanes used to communicate between the CPU and other major parts of the computer

Basic CPU Architecture



Basic CPU Architecture

- There are three types of buses:
  - **Control bus** – carries status signals between the CPU and other devices
  - **Address bus** – carries address signals to indicate where data should be read or written to in the system's memory
  - **Data bus** – carries the actual data that is being read from or written to system memory

Top 9 Cases Behind 100% CPU Usage

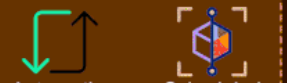
ByteByteGo

Infinite Loops

```
while(1) {
    executeTask () ;
}
```

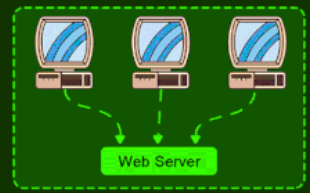
coding errors when a loop condition never fails

Background Processes



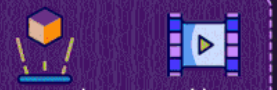
system services running silently in the background but consuming high CPU

High Traffic Volume



web servers get overwhelmed by sudden user traffic spikes

Resource-Intensive Applications

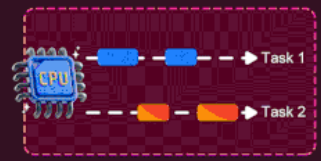


CPU intensive calculations such as video editing and simulations

Insufficient Memory

CPU is overworked compensating for the lack of adequate RAM

Concurrent Processes



multiple applications running at the same time, competing for CPU resources

Busy Waiting

performing repeated checks means the processor isn't available for other tasks

RegEx Matching

^[Reg]ular [Ex]pressions$

inefficient regex patterns and greedy qualifiers can trigger excessive backtracking

Viruses & Malware

malicious software that hijacks system resources to perform unauthorized tasks

Basic CPU Architecture

CPUs can be **classified** by hardware elements:

- **Design type**
- **Speed**
- **Cache**
- **Address bus**
- **Data bus**
- **Control bus**
- **CPU scheduling**

Design Type

- Two general CPU designs are used today:
  - **Complex Instruction Set Computing (CISC)**
  - **Reduced Instruction Set Computing (RISC)**
- Main difference between the two design types is **the number of different instructions** the chip can process
- CPUs can process as many as **20 million** (low-end) to **several billion** (high-end) operations per second
- **Instruction set** – **list of commands** the CPU can understand and carry out

Design Type

- CISC and RISC CPUs differ in the following ways:
  - **Complex** versus **simple** instructions
    - CISC CPUs are generally more complex
  - **Clock cycles**
  - **Pipelining**
    - The ability of the CPU to perform more than one task on a single clock cycle
  - **Hardware versus microcode**
    - Small program inside the chip that interprets and executes each instruction

Design Type

- CISC and RISC CPUs differ in the following ways:
  - **Compiler**
    - A computer program that takes a high-level language and turns it into assembly code that is executed by the CPU
  - **Number and usage of registers**
    - CISC CPUs have **fewer registers** than a RISC CPU

Speed

- The speed of a CPU **defines how fast it can perform operations**
- Most obvious indicator is the **internal clock speed**
  - Clock provides a rigid schedule to make sure all the chips know what to expect at what time
  - The faster the clock, the faster the CPU
- As more components are needed to make a CPU, the chip uses more energy, which is converted to heat.
  - CPUs require fans to keep cool

Speed

- CPU must be able to communicate with other chips in the computer
  - Uses an **external clock speed** to communicate with the rest of the computer
  - External clock speed runs **slower** than the internal clock speed
    - Typically **one-half, one-third, one-fourth, or one-eighth** the speed of the internal CPU clock

Cache

- Since internal clock *is* ***faster*** *than* the external clock
  - The CPU would have to wait on information to arrive from other parts of the computer
- Most modern CPUs have cache memory built into the chip
- While CPU is executing program code
  - Instructions or data that are most likely to be used next are fetched from main memory and placed in cache memory

Cache

- There are different levels of cache
  - **Level 1 (L1) cache** is the fastest and usually runs at the same speed as the CPU
  - **Level 2 (L2) cache** is slower but much larger
  - **Level 3 (L3) cache,** until the last several years, was not part of the CPU chip, but part of motherboard
  - **Level 4 (L4) cache** will usually be found on motherboard (if it exists)
- **Cache controller** – predicts what data will be needed and makes the data available in cache before it is needed

Address Bus

- **Address Bus** – internal communications pathway that specifies the source and target addresses for memory reads and writes
  - Typically **runs at the external clock spe**ed of CPU
  - Width of the address is the number of bits that can be used to address memory
    - Wider bus means the computer can address more memory and store more data
  - Modern processors use a **64-bit** address bus
    - Allows them to address **16 terabytes (TB) of memory**

Data Bus

- The data bus allows computer components, such as CPU, display adapter, and main memory, to **share information**
- The number of bits in the data bus indicates how many bits of data can be transferred **from memory to the CPU in one clock tick**
  - **A CPU with an external clock speed of 1 GHz and a 64-bit data bus could transfer as much 8 GB per second**
- A CPU with a 64-bit data bus typically can perform operations on 64 bits of data at a time

Control Bus

- Information is transported on the **control bus** to keep the CPU **informed about the status of resources and devices connected to the computer**
- Memory read and write status is transported on this bus, as well as interrupt requests
  - **Interrupt request (IRQ)** – a request to the processor to “interrupt” whatever it is doing to take care of a process, which in turn might be interrupted by another process

CPU Scheduling

- CPU Scheduling – **determines which process to start given the multiple processes waiting to run**
- Beginning with Windows NT, use of CPU scheduling began to evolve to allow multithreading
  - **Multithreading** is the ability to run two or more processes (known as threads) at the same time
  - A **thread** is the smallest piece of computer code that can be independently scheduled for execution
  - **Hyper-Threading** allows two threads to run on each CPU core simultaneously

Popular PC Processors

Intel

- Most popular CPU manufacturer today
  - 8088 – CPU found in the original IBM PC
  - Early Intel processors were identified by model numbers: 8088, 8086, 80286, 386, 486 (sometimes preceded by an i as in i486)
  - Pentium family of chips followed 486 and are sometimes identified by a P and a number (example – P4)
  - Intel Itanium and Itanium 2 are newer 64-bit processors for high-end PCs and server

Intel

- Intel Itanium and Itanium 2 processors are different from previous ones in two respects:
  - Built on the RISC-based EPIC architecture
  - 64-bit chips
  - In order to use the capabilities of 64-bit processing, the **operating system and applications must be rewritten to use 64-bit**
  - Windows XP, Windows Server 2003 Enterprise, Windows Server 2003 Datacenter, and Windows Server 2008 can run on Itanium 64-bit processors

Intel

- Initially, processors were developed with one core
  - Today, many multicore Intel CPUs are available
  - Even smartphones and tablets frequently contain two or four cores
- Microarchitecture is:
  - The description of a CPU’s internal circuitry
  - Defining characteristics (technology used to create the chip)
  - Supported instruction set
  - Bit size

Intel

Table 3-2 Multicore Intel CPUs

CPU	Year introduced	Cores	Speed	Bus speed	Cache
Pentium D	2005	2	2.64–3.60 GHz	533–1055 MHz	1–2 MB
Xeon	2005	2–8	1.68–3.73 GHz	667–1600 MHz	2–24 MB
Itanium	2006	2–4	1.40–1.73 GHz	400–667 MHz	8–24 MB
Intel Core Solo	2006	1	1.06–1.86 GHz	533–667 MHz	2 MB
Intel Core Duo	2006	2	1.06–2.33 GHz	533–667 MHz	2 MB
Pentium Dual-Core	2007	2	1.60–3.33 GHz	800–1066 MHz	1–2 MB
Intel Core 2 Duo	2007	2	1.86–3.33 GHz	800–1333 MHz	3–6 MB
Intel Core 2 Quad	2007	4	2.33–3.00 GHz	1066–1333 MHz	4–12 MB
Intel Core 2 Extreme	2008	2	2.00–3.20 GHz	1066–1600 MHz	6–12 MB
Atom	2008	1	800 MHz–2.13 GHz	400–533 MHz	512 KB–1 MB
Intel Core i7	2009	4–6	1.06–3.33 GHz	2.5 GT/s–4.8 GT/s	4–12 MB
Intel Core i5	2009	2–4	1.06–3.76 GHz	2.5 GT/s	3–8 MB
Intel Core i3	2010	2	1.20–3.06 GHz	2.5 GT/s	4 MB

AMD

- Advanced Micro Devices, Inc. (AMD)
  - Manufactures CPU chips that compete with Intel
- AMD continues to develop CPUs with names based on:
  - The series, such as Athlon and FX
  - And the core architecture, such as Zambezi and Vishera

AMD

Table 3-4 Multicore AMD processors

Processor	Clock speeds (MHz or GHz)	Cores	Compares to intel chip
Athlon II	1.8–3.3 GHz	2–4	Intel Core 2 Duo
Phenom II	2.5–3.5 GHz	2–6	Intel Core 2 Quad
Phenom	1.8–2.6 GHz	3–4	Intel Core 2 Quad
Athlon X2	2.3–2.8 GHz	2	Intel Core 2 Duo
Opteron 4000 Series	1.7–2.8 GHz	8–12	Itanium/Xeon
Opteron 6000 Series	1.7–2.4 GHz	6	Itanium/Xeon

Table 3-4 Multicore AMD processors

Other Processors

- **Motorola 68xxx** – were typically found in Macintosh computers and older UNIX
- **PowerPC** – line of chips that used different instructions sets than the Motorola 68xxx line
  - Developed jointly by Apple Computer, IBM, and Motorola (AIM)
  - In 2005, Apple moved to using Intel chips
- **SPARC** – Scalable Processor Architecture
  - A RISC processor designed by Sun Microsystems
  - SPARC M7 is the current version
    - A 64-bit chip with 64-bit address and data buses

Other Processors

- **Alpha** – CPU originally designed by Digital Equipment Corporation (DEC), which was purchased by Compaq, which was purchased by HP
  - Found in older high-end HP Compaq servers
  - Had a 64-bit data and address bus
  - Was the first chip to reach a speed of 1 GHz
  - Were found in computers conducting heavy networking, engineering, and graphics duties
  - There were many proprietary devices that ran custom OSs based on the Alpha architecture

Summary

- One of the **main functions of the operating system is to provide the interface between the various application programs running on a computer and the hardware inside**
- Most CPUs are composed of **a control unit, arithmetic logic unit, registers, and a system bus, which is composed of a control bus, address bus, and data bus**

Summary

- CPUs can be **classified by** several elements, including **design type, speed, cache, address bus, data bus, control bus, and CPU scheduling**
- The **amount of cache is cri**tical to CPU's overall **speed** because it is much faster than RAM

Summary

- CPU scheduling allows an operating system to schedule multiple processes or threads
- Intel processors are the most popular CPUs today, but AMD processors are frequently used
- Other processors include the Motorola, PowerPC, the SPARC, and the Alpha