

Software Interface and Computer Organization

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Content

Books

Computer Organization and Design:
The Hardware/Software Interface-
RISC-V Edition, 5th Edition, 2017

Chapter-2

David A. Patterson and John L.
Henessey

Computer Systems: A Programmer's
Perspective, 3rd Edition, 2016

Chapter-1

Randal E. Bryant and David R.
O'Hallaron

Objectives

- Learn how the programs get converted into binary or executable
- Learn what's there when we open the box: Physically and Logically
- Map a binary to the runtime environment
- Appreciate the role of Operating Systems in Program Management

Source to Binary: Importance of Compilers and Assemblers

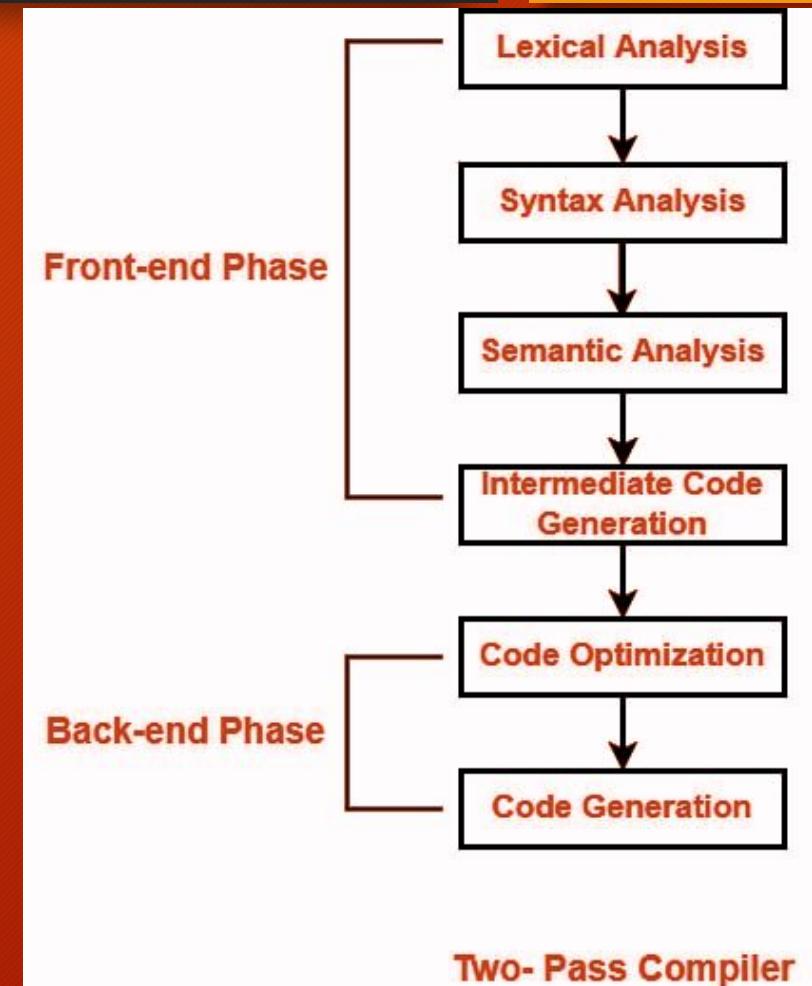
Instruction Set

The vocabulary of commands understood by a given architecture

Compiler

The compiler turns the source language program into an assembly program

- Lexical Analysis: Parses the program into tokens by scanning the file
- Syntax Analysis: Validates against the grammar of language to build the parse tree
- Semantic Analysis: Checks the meaning of the code, type management, other errors related to syntax
- Intermediate Code Generation: Generates assembly code. This phase generates an intermediate code that can be transformed into machine code.
- Code Optimization: Removes dead code, reorder instructions and many more stuff
- Code Generation: Generate final assembly code after optimization



Stored Program Concept

The idea that instructions and data of many types can be stored in memory as numbers and thus be easy to change, leading to the stored-program computer.

Assemblers

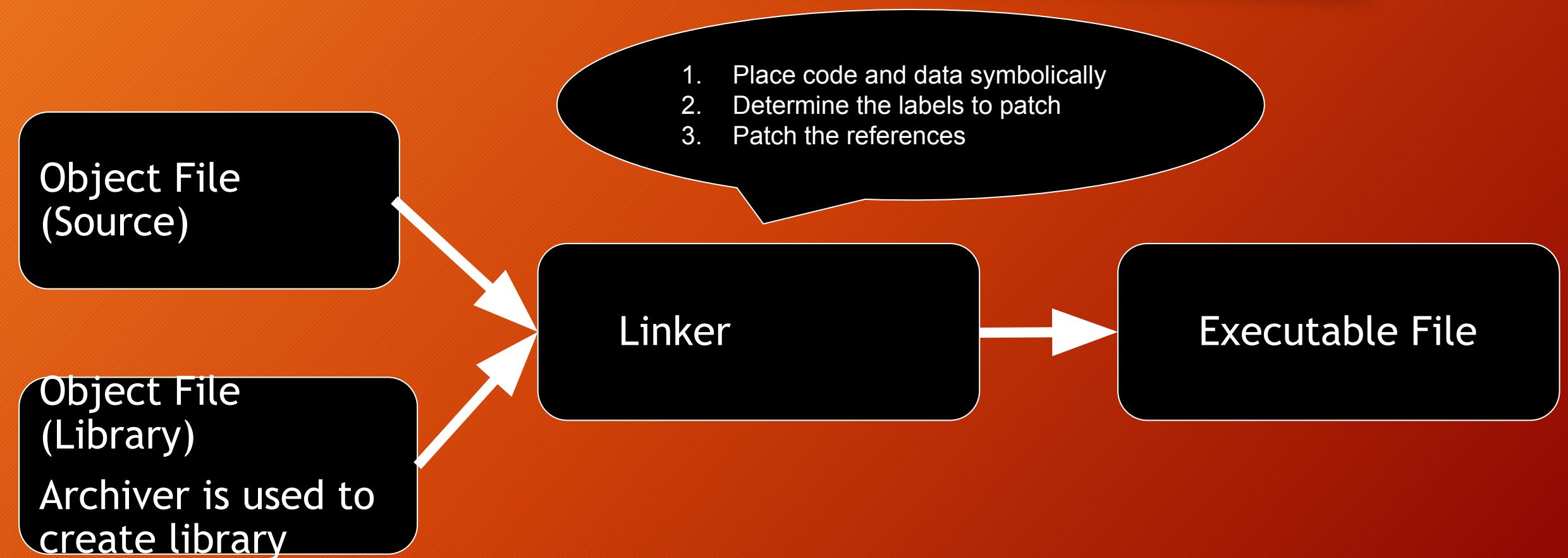
- The assembler turns the assembly language program into an object file, which is a combination of machine language instructions, data, and information needed to place instructions properly in memory.
- Assemblers keep track of labels used in branches and data transfer instructions in a symbol table.
- Symbol table matches names of labels to the addresses of the memory words that instructions occupy

Assembly Code

Assembler

Object File

Linker



Object File

Header: Specifies size and position

Relocation information: Move code anywhere

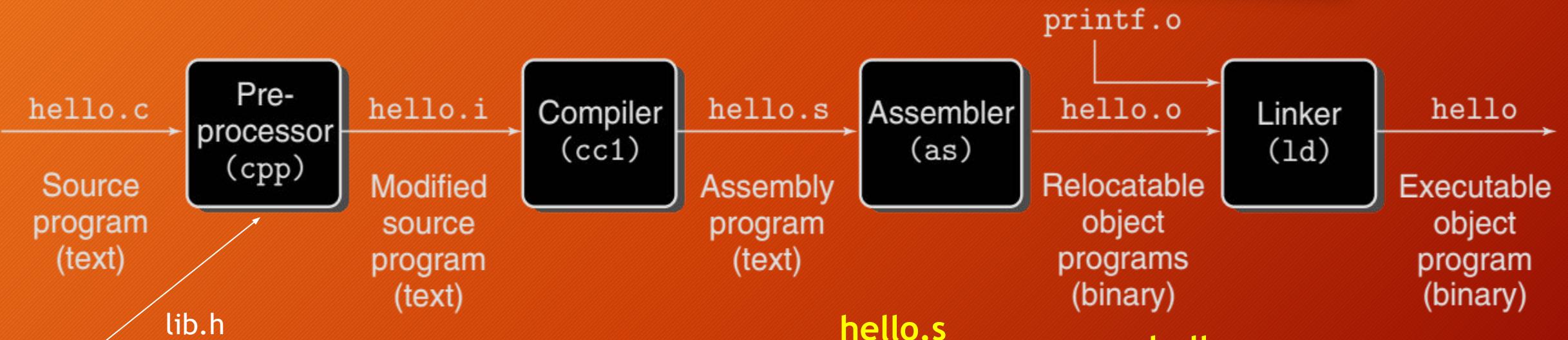
Code in form of machine language

Symbol Table

Static and Extern Data

Debugging Information: Did you use gdb?

The Compilation Overview



hello.c

```
1 #include <stdio.h>
2
3 int main()
4 {
5     printf("hello, world\n");
6     return 0;
7 }
```

hello.i

Code including header files

hello.s

```
1 main:
2     subq    $8, %rsp
3     movl    $.LC0, %edi
4     call    puts
5     movl    $0, %eax
6     addq    $8, %rsp
7     ret
```

hello.o

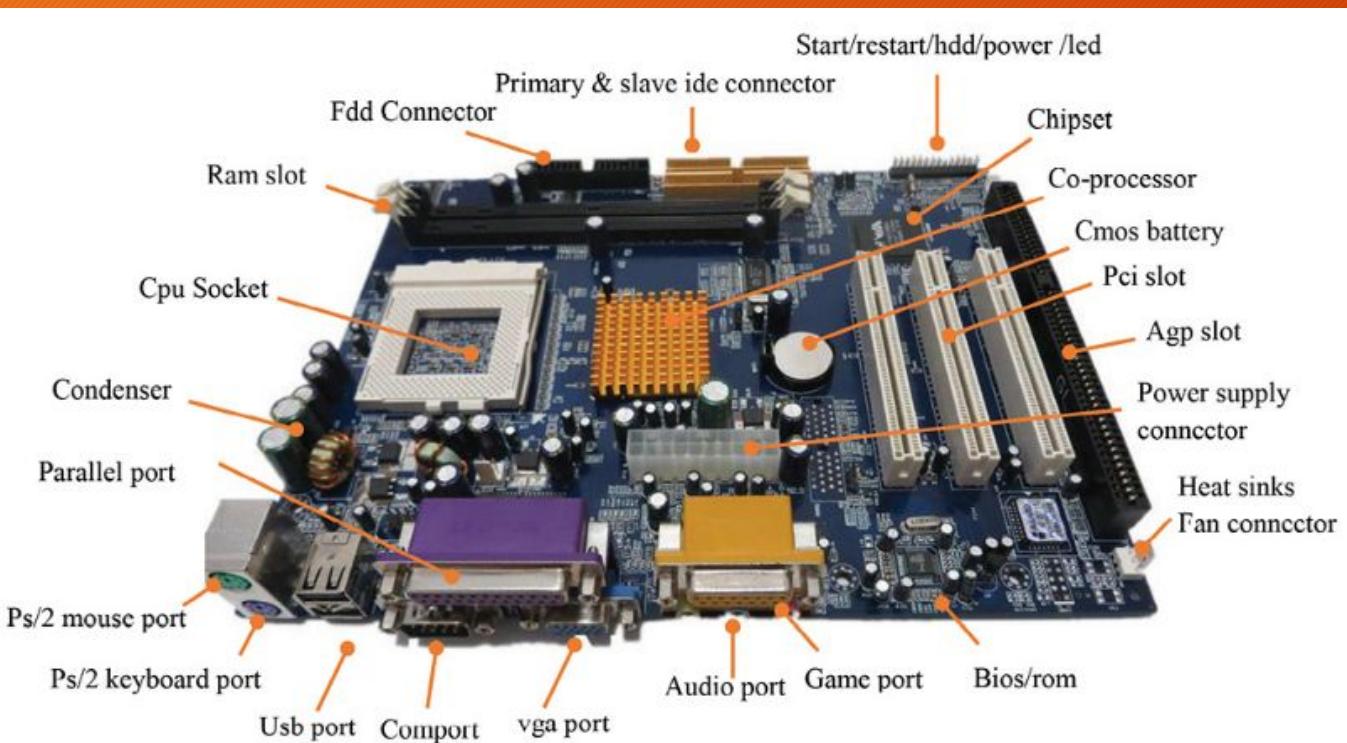
```
010101
110111
011101
010001
010100
000101
```

hello

```
010101
111111
011101
011001
010100
000101
```

Open the Box:
Both Logically and Physically

Motherboard



Form Factor

ATX (Advanced Technology Extended) - Typical Desktop
E-ATX- Gaming and powerful desktop/workstations
Micro-ATX -Smaller Computers
Mini ITX (Information Technology eXtended) - Smaller Compact PCs
Thin Mini ITX - Laptops/Mini-desktops
Mini-STX-Embedded Boards
SSI CEB (Server System Infrastructure - Custom Electric Board)
SSI EEB (Server System Infrastructure - Enhanced Extended Board)

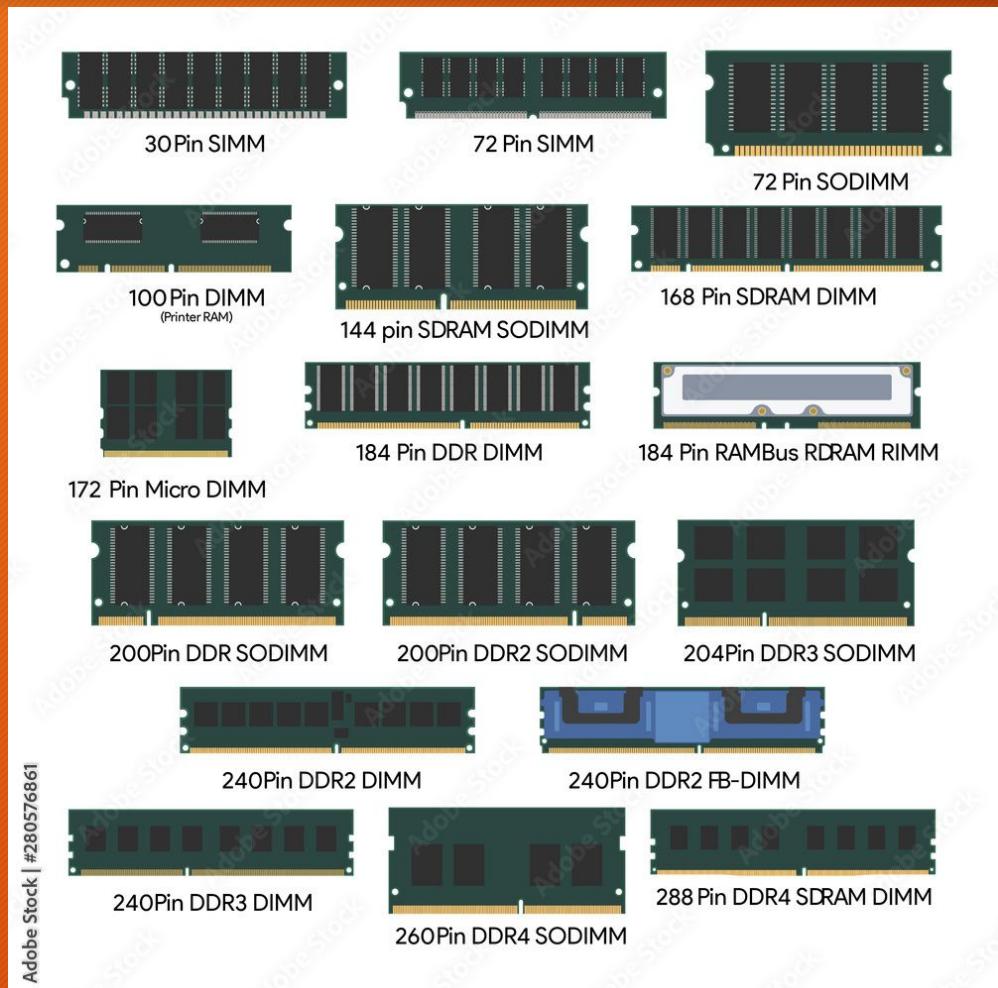
Major Manufacturers

ASUS, Gigabyte, ASRock, Supermicro, MSI (Micro-star International), Biostar, Dell, HP, Lenovo

The CPU Product Line



The Memory Product Line



Adobe Stock | #280576861

Categories

Main Memory
GPU/TPU Device Memory

Generations

SIMM
DIMM
SDRAM DIMM
RDRAM DIMM
DDR DIMM
DDR2 DIMM
DDR3 DIMM
DDR4 DIMM
DDR5 DIMM
GDDRX DIMM

Major Manufacturers

Kingston, Micron, Samsung, Corsair, ADATA, Intel, Transcend, etc

The SSDs



PCIe SSD



SATA SSD

Categories

PCIe M.2 SSD: Connects north bridge, Faster, Costlier

SATA SSD: Connects south bridge, Slower, Cheaper

Major Manufacturers

Kingston, Micron, Samsung, Corsair, ADATA, Intel, Transcend, etc

PSUs and Cooler



Categories

Bronze, Gold, Platinum, Titanium -> Ranging from 350W to 2000W

Major Manufacturers

ASUS, Gigabyte, Corsair, Cooler Master, EVGA, Deep cool, etc.

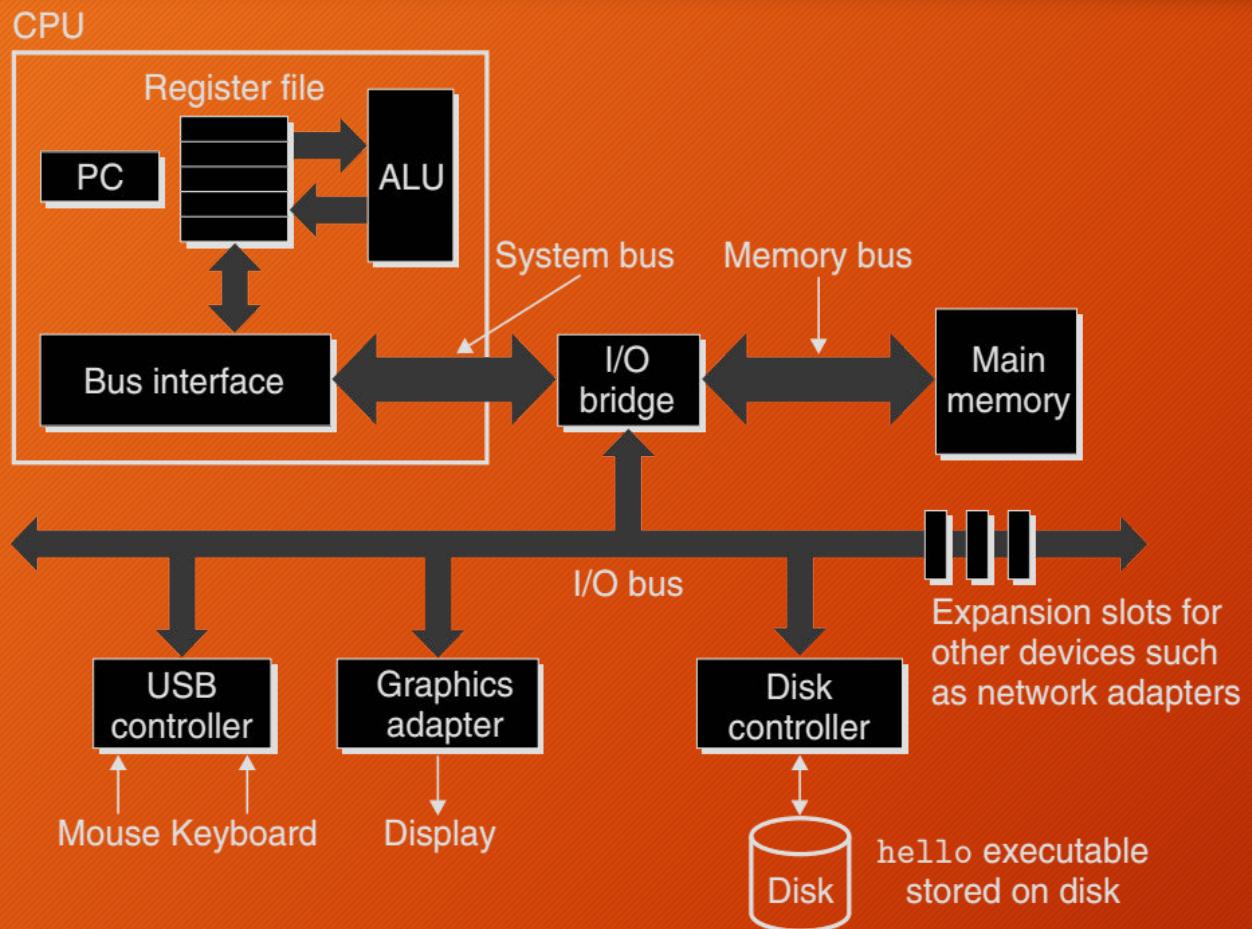
Categories

Tower Cooler, Liquid Cooler, Cooling Paste

Major Manufacturers

Stock Cooler, Corsair, Cooler Master, EVGA, Deep cool, etc.

A Generic Logical Organization



Computes: CPU, GPU, NPU, TPU, etc

Memory: System Memory/Main Memory

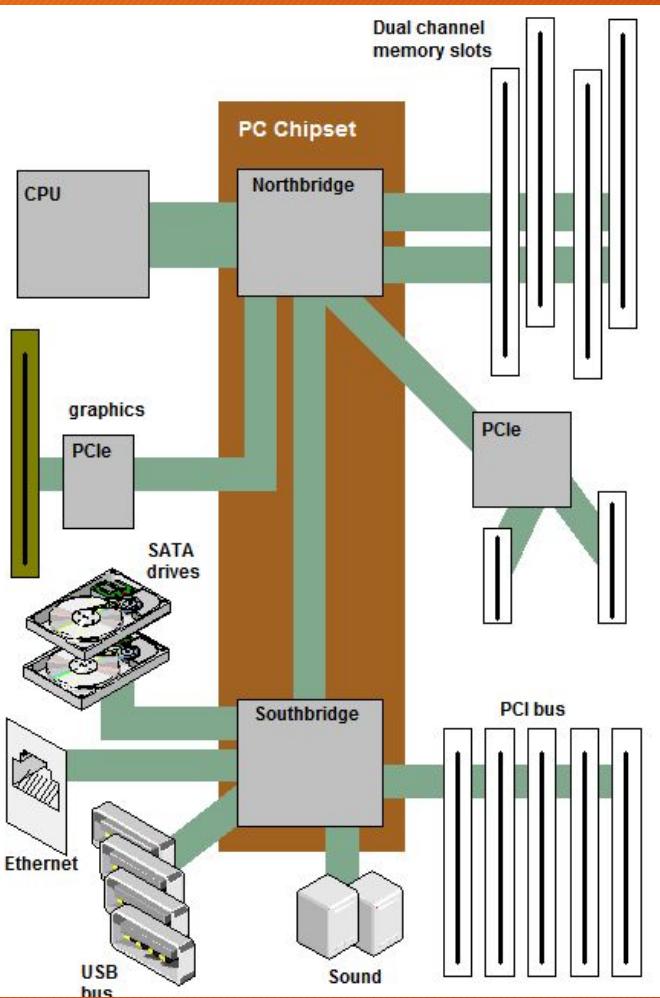
Devices: Disk, Display, Mouse, Keyboard, Network Ports

Device Controllers: Disk Controller, Display Adapter, USB Controller

Buses/Interconnects: System Bus, Memory Bus, IO Bus, Internal Buses

Bridges: North and South Bridge

System-On-Chip, North and South Bridge

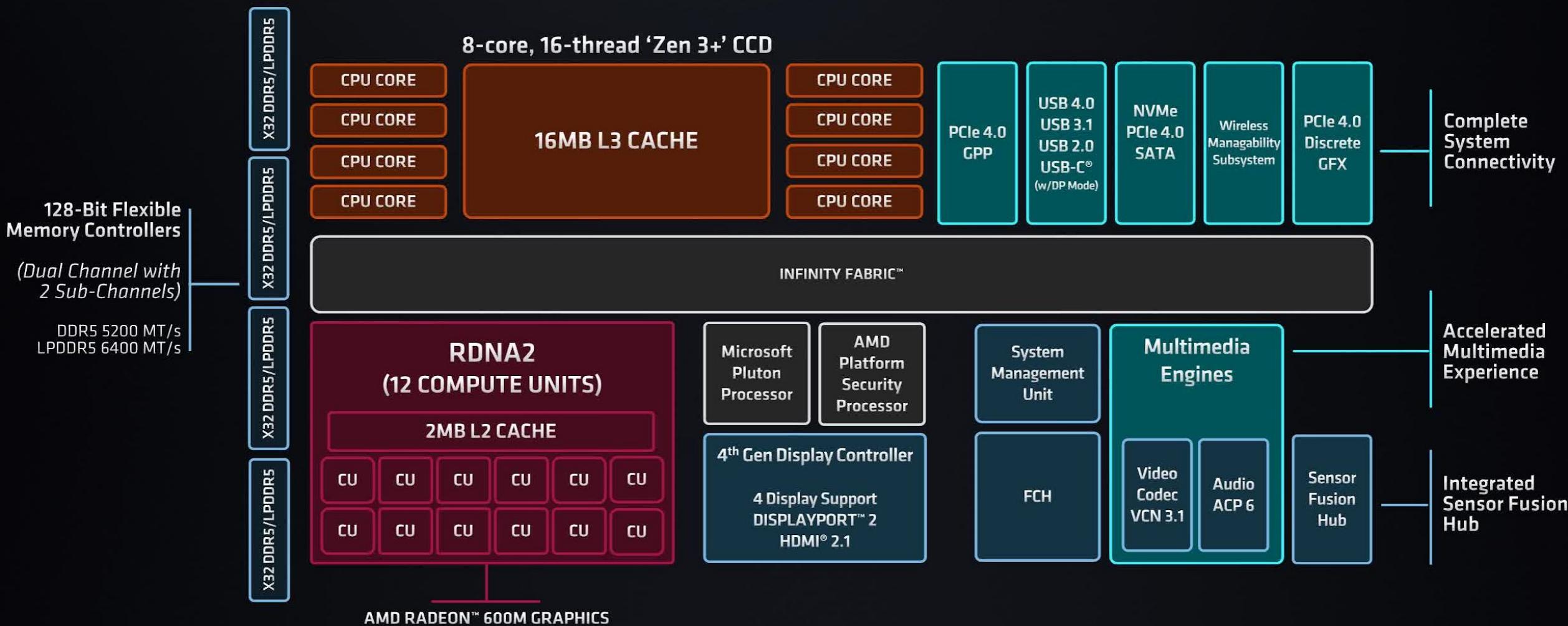


System-on-chip integrates multiple electronic components required for a complete system onto a single chip.

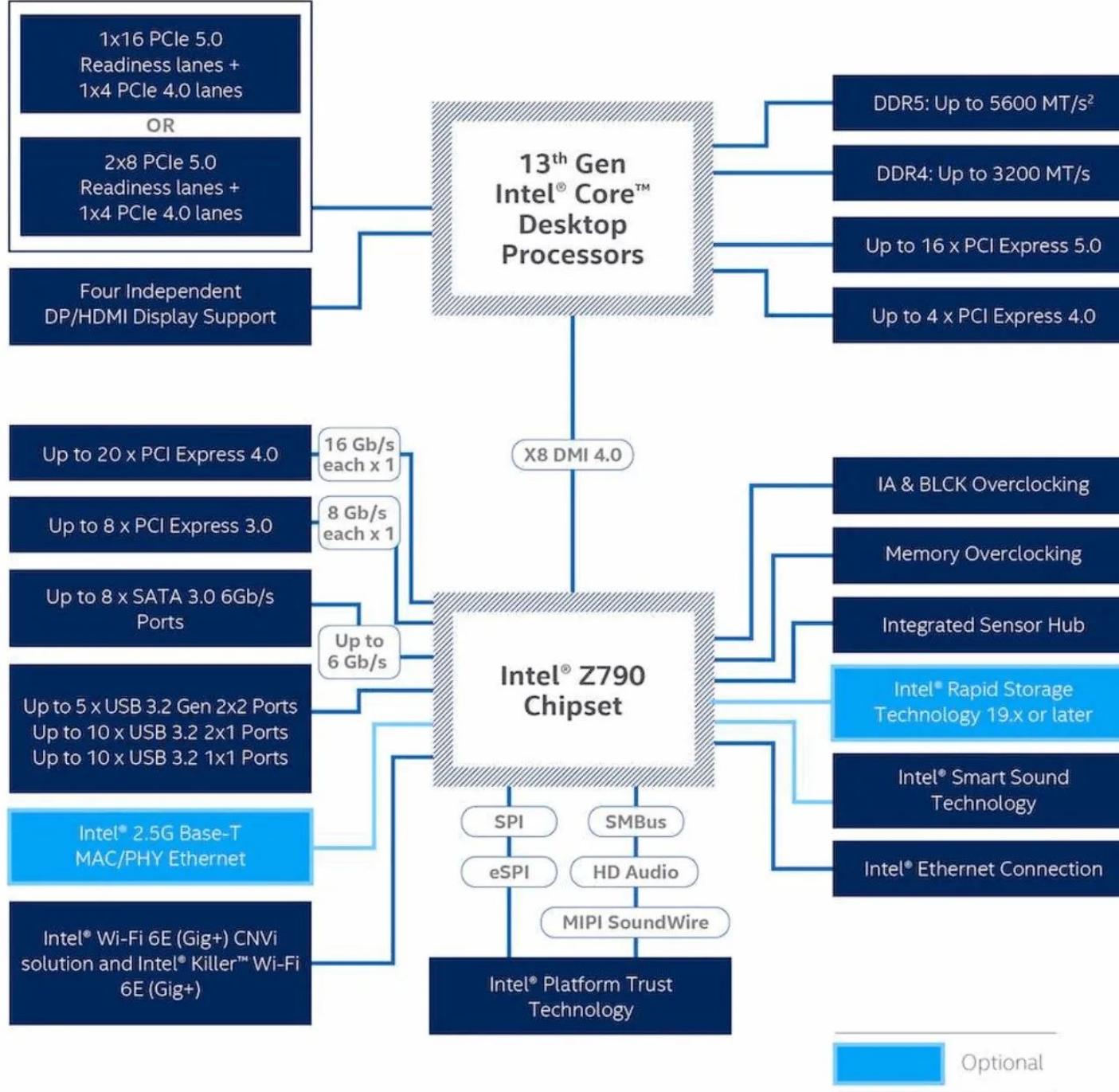
North Bridge is a the fast bridge that connects all devices that operate at high frequency and are used very frequently. Ex: CPU, Memory Modules, GPUs

South Bridge is the slow bridge that connects all devices that operate at lower speed and are used very infrequently. Ex: IO devices like Ethernet, SATA SSD/HDD, Sound Card

System-on-chip (AMD Zen 4 Architecture)

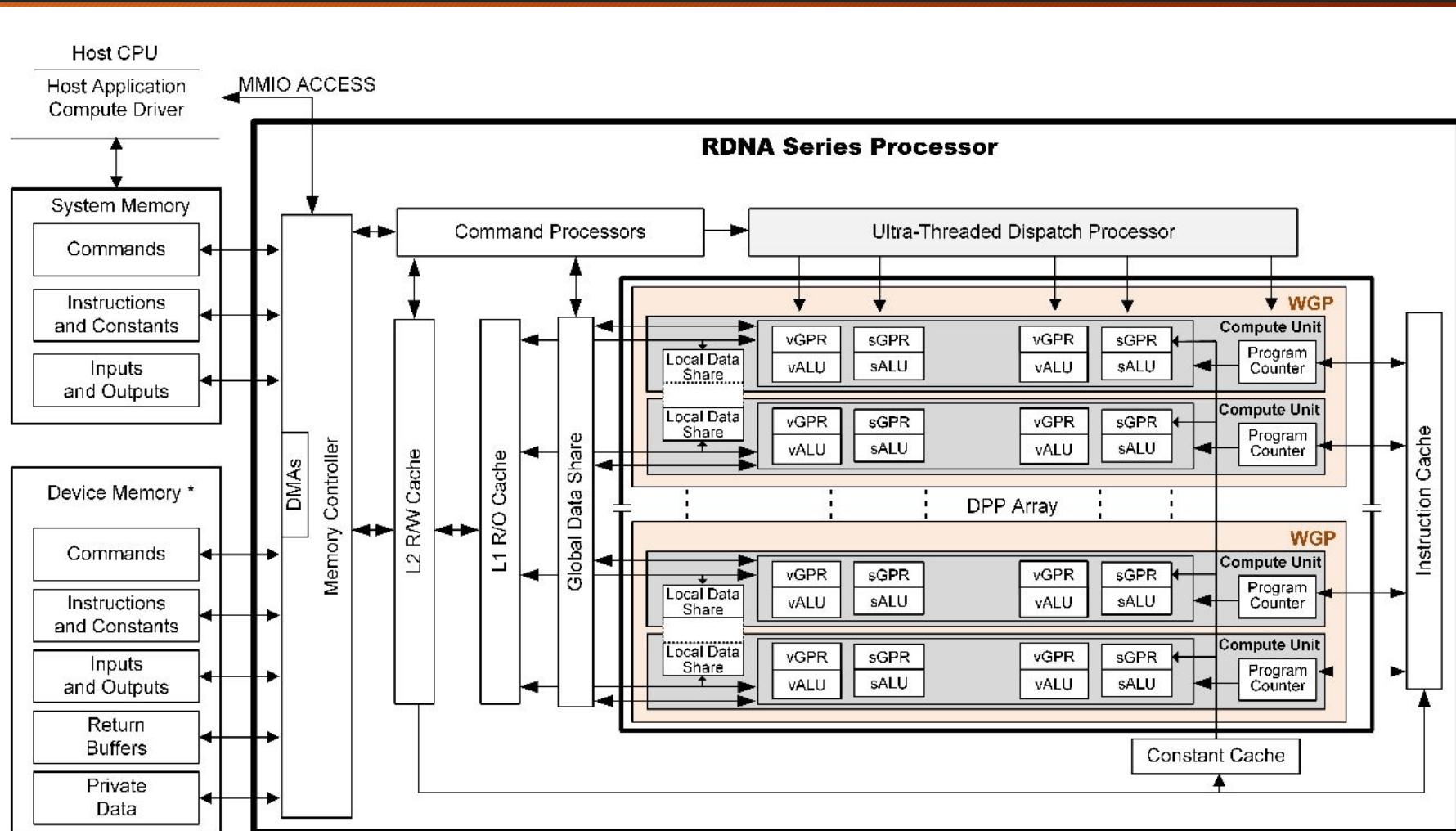


System-on-chip (Intel Meteor lake)



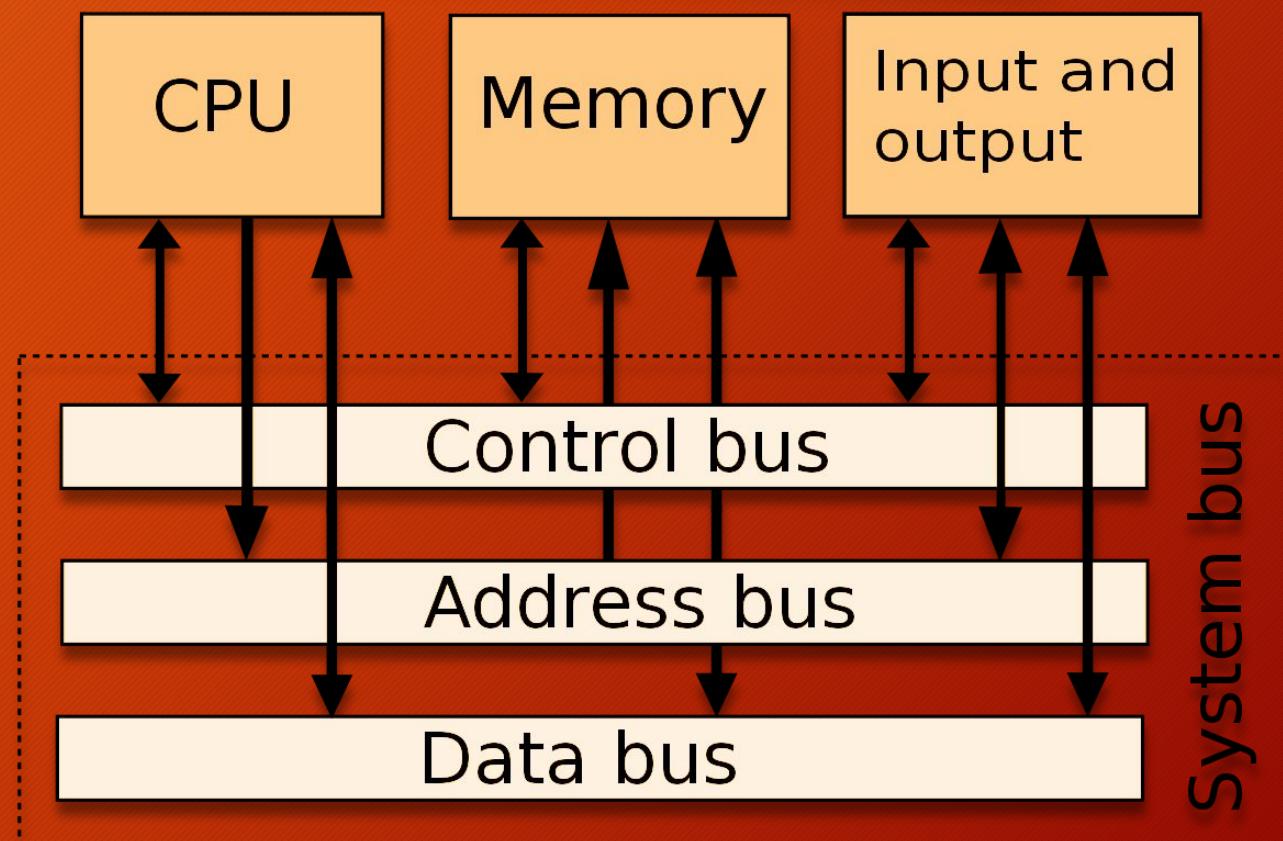
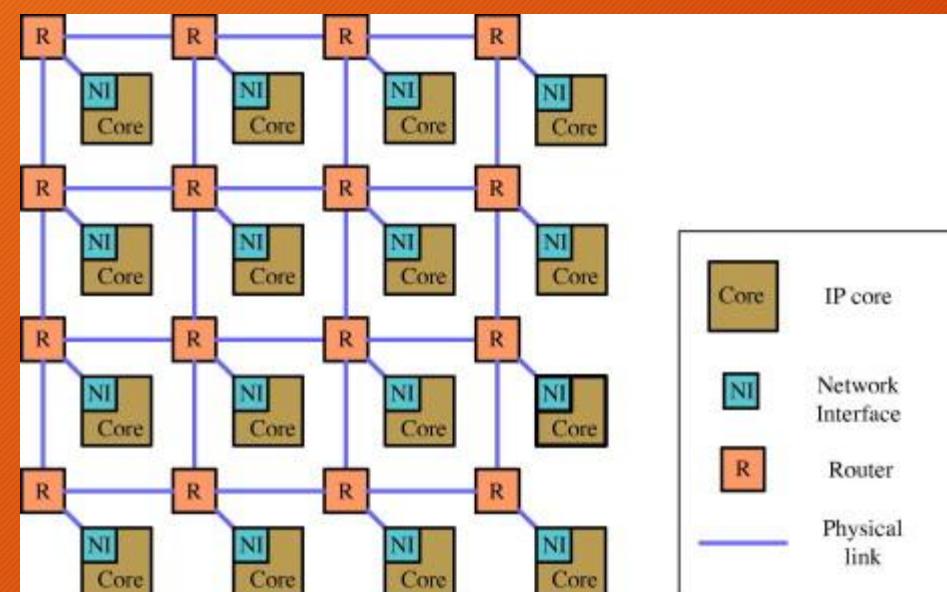
Graphics Processing Unit

System-on-chip (AMD RDNA GPU)

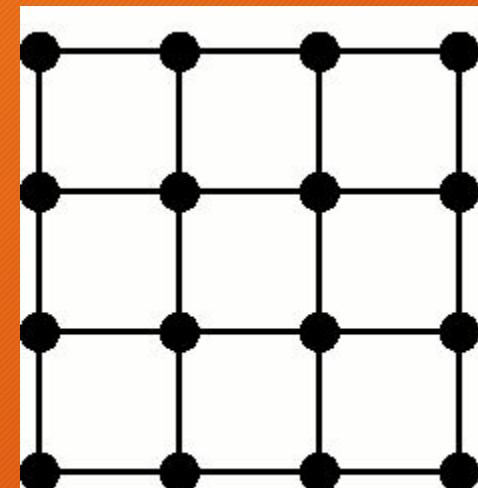


Network-On-Chip: Buses and Interconnects

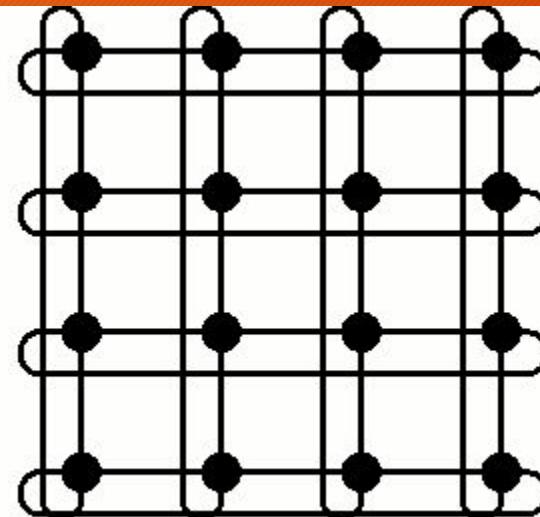
- Connects different units
- Transfers control signals
- Transfers address
- Transfers data



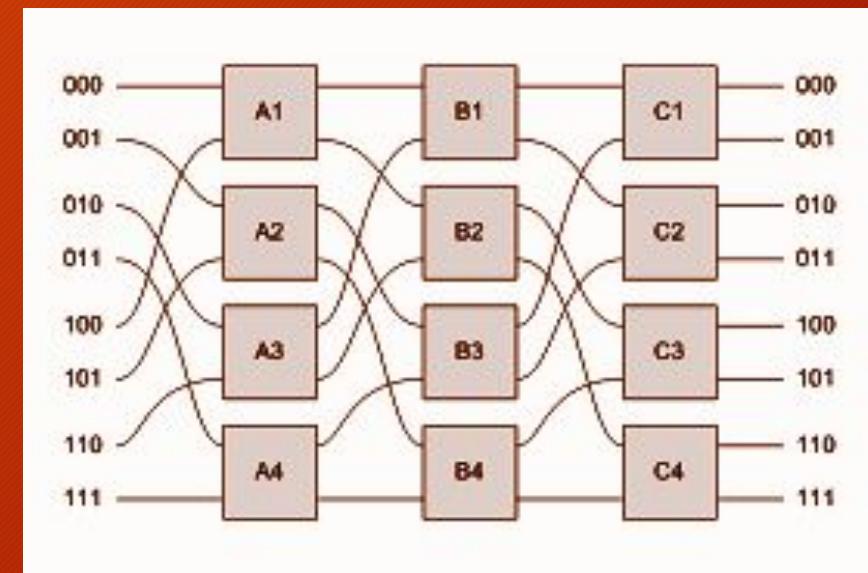
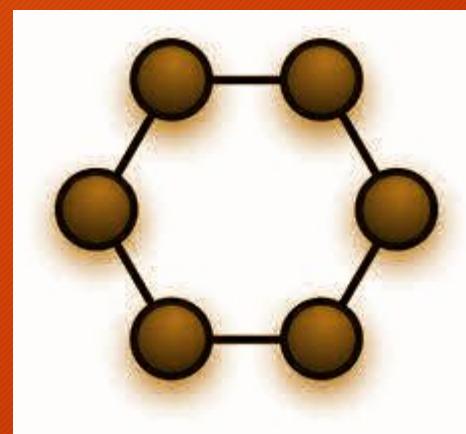
Multi-core Processors: Interconnection Network



(a) 2D-Mesh

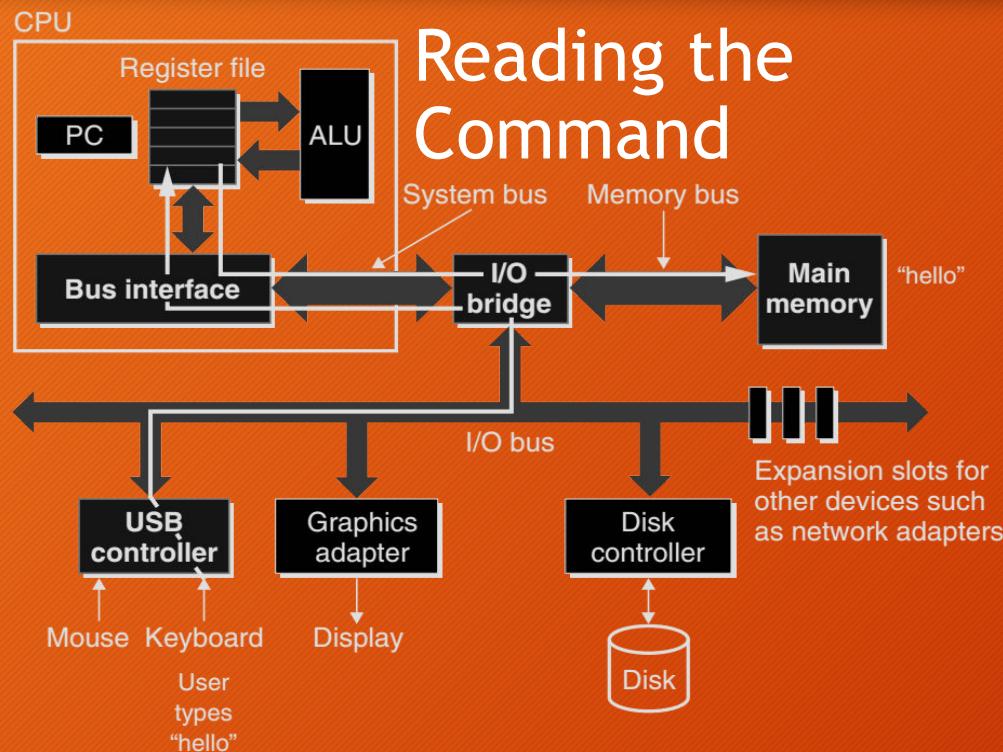


(b) 2D-Torus



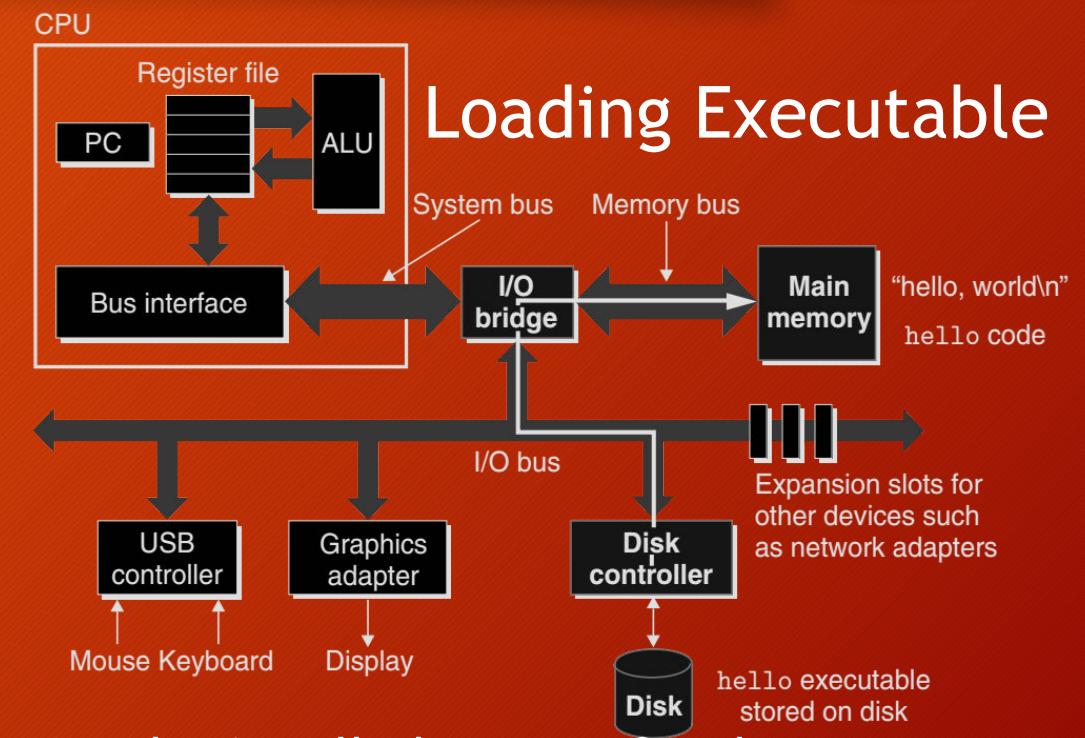
The Runtime Inception: Algorithms to Execute Algorithms

Runtime: Reading Command and Loading an Executable



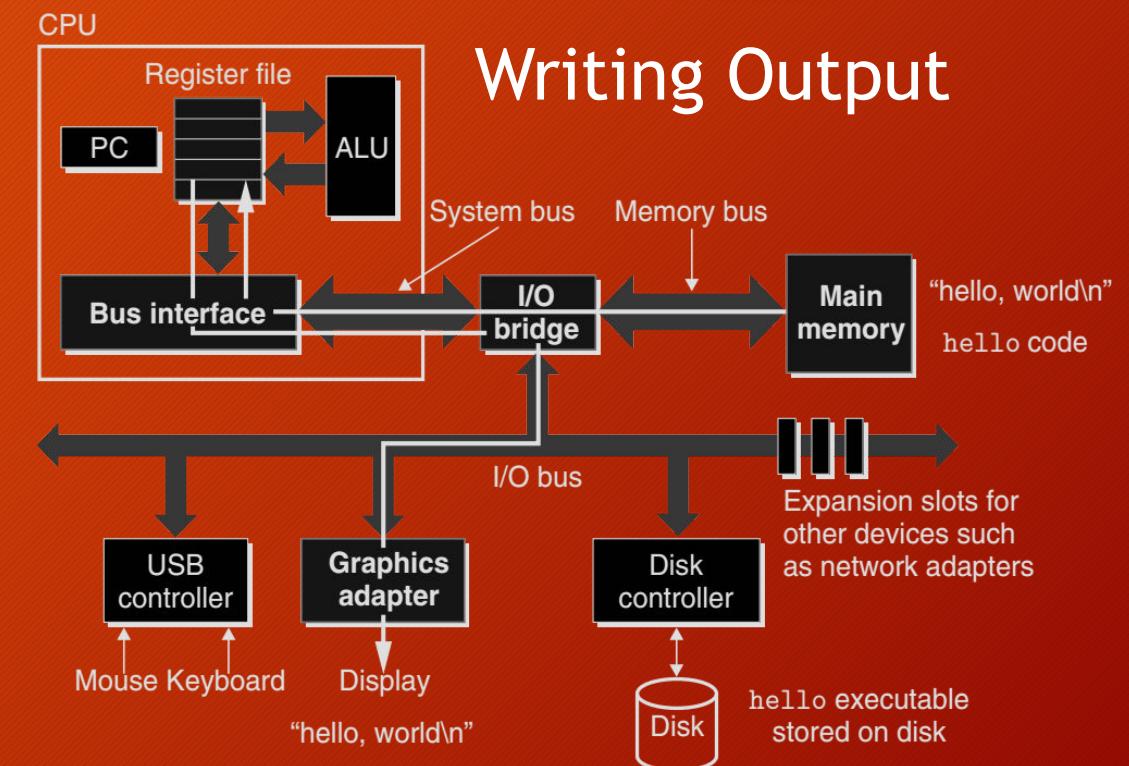
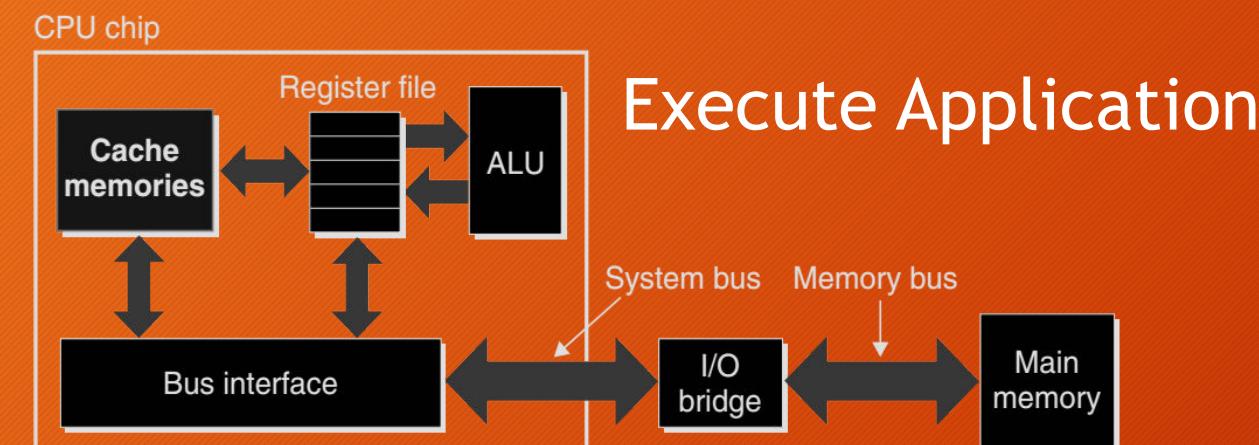
OS is already running a shell program

Shell receives a keyboard interrupt to load "hello" into the memory



Loader is called to transfer the binary from disk to main memory using DMA

The Runtime: Application Execution and Writing Output



The Core Execution: CPU/GPU/NPU/Accelerator

Instruction handling unit	Data handling unit (load store unit)	Register Set	Execution Unit	Control Unit
<ul style="list-style-type: none">• Reading instruction• Decoding instruction	<ul style="list-style-type: none">• Reading memory• Writing memory	<ul style="list-style-type: none">• Reading registers• Writing registers	<ul style="list-style-type: none">• Arithmetic and logic unit• Floating point unit• Integer unit	<ul style="list-style-type: none">• Hardwired Controlled• Micro-programmed Controlled

The Memory

Main Memory

- Typically, embedded boards ~ 2/4 GB, Mobile ~ 4/8/16 GB, Laptops/Desktops ~ 8/16/32 GB, Workstations ~ 64/128 GB, Servers ~ 128GB/2TB
- OS-controlled allocation
- Hardware-controlled access

Secondary Storage

- TBs now for laptops, desktops, workstations, servers
- OS-controlled allocation/access

Cache Memory (8KB to 64 MB)

- Hardware-controlled allocation/access

Main Memory



Storage is external to the processor



CPU performs read and write operations on the main memory



Who allocates data in main memory? OS



How many of the operands are memory addresses in an instruction?

Thank You!