Computer Hardware and OS (1/2)

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Topics Covered

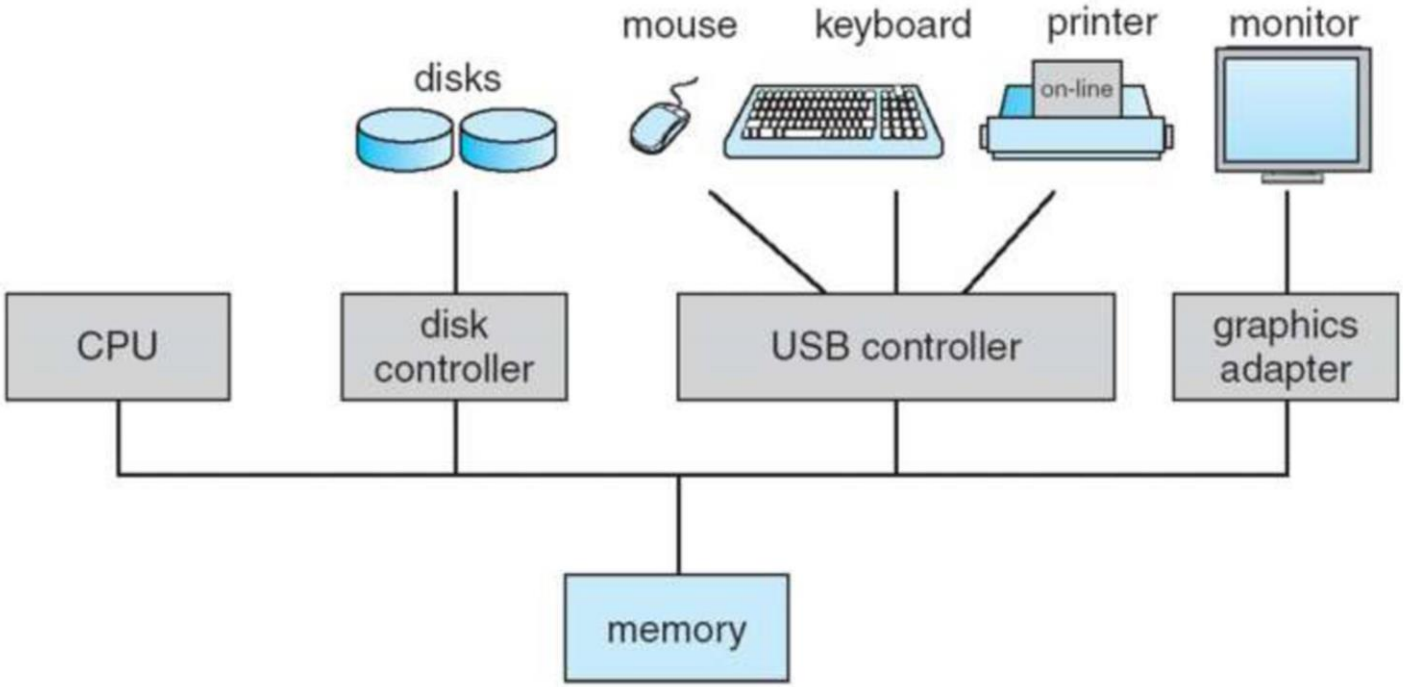
I. Computer Organization and Instruction Processing

II. Program Execution

Computer System Elements

- **Processor (or CPU)**
  - Controls system operation
- **Main Memory**
  - Volatile, stores data and programs
  - Also called "real memory" or "primary memory"
- **I/O Modules**
  - Move data between computer and external environment, such as hard disk, display, keyboard, etc.
- **System Bus**
  - Facilitates communication among processors, main memory, an d I/O modules

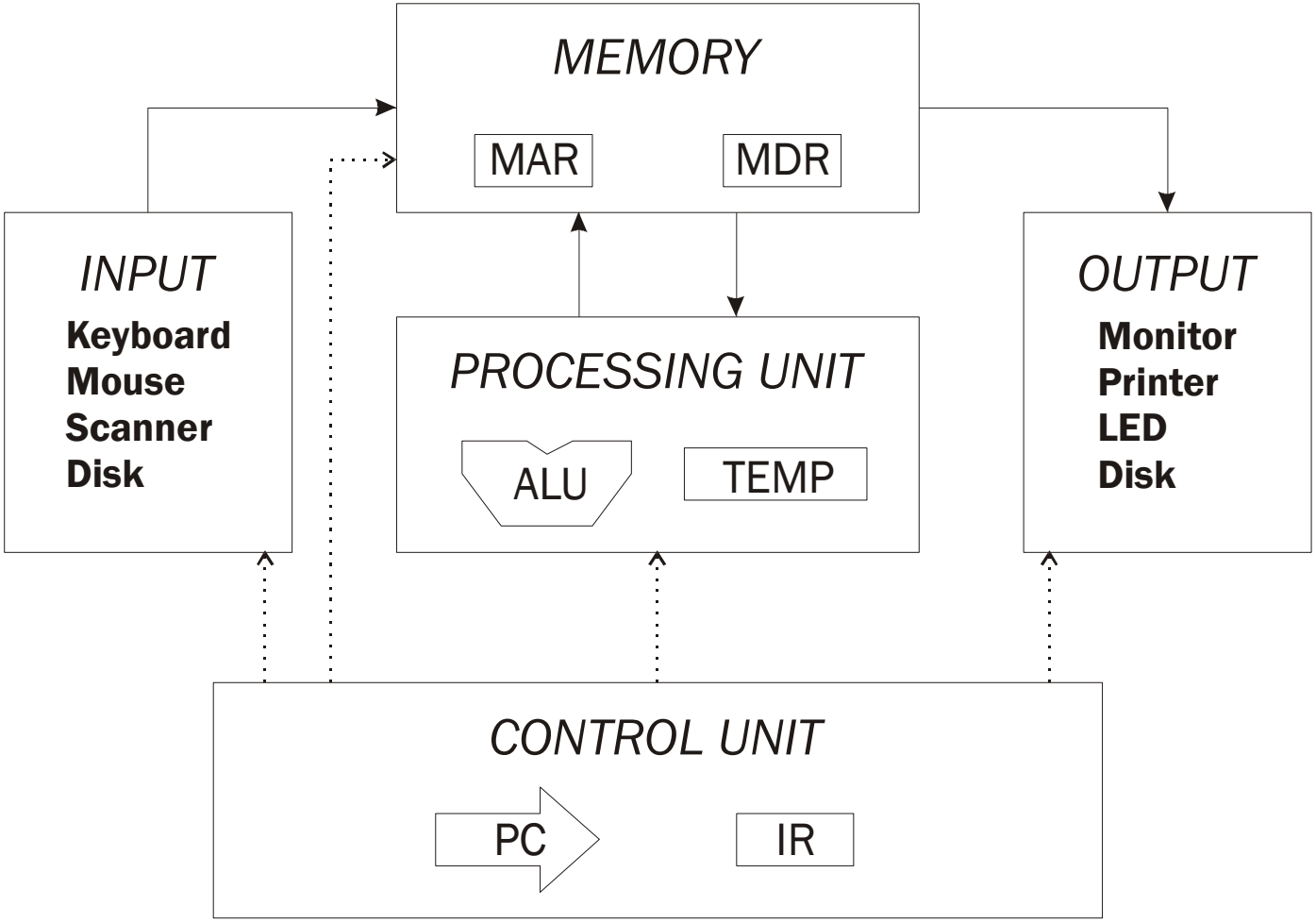
Computer Organization



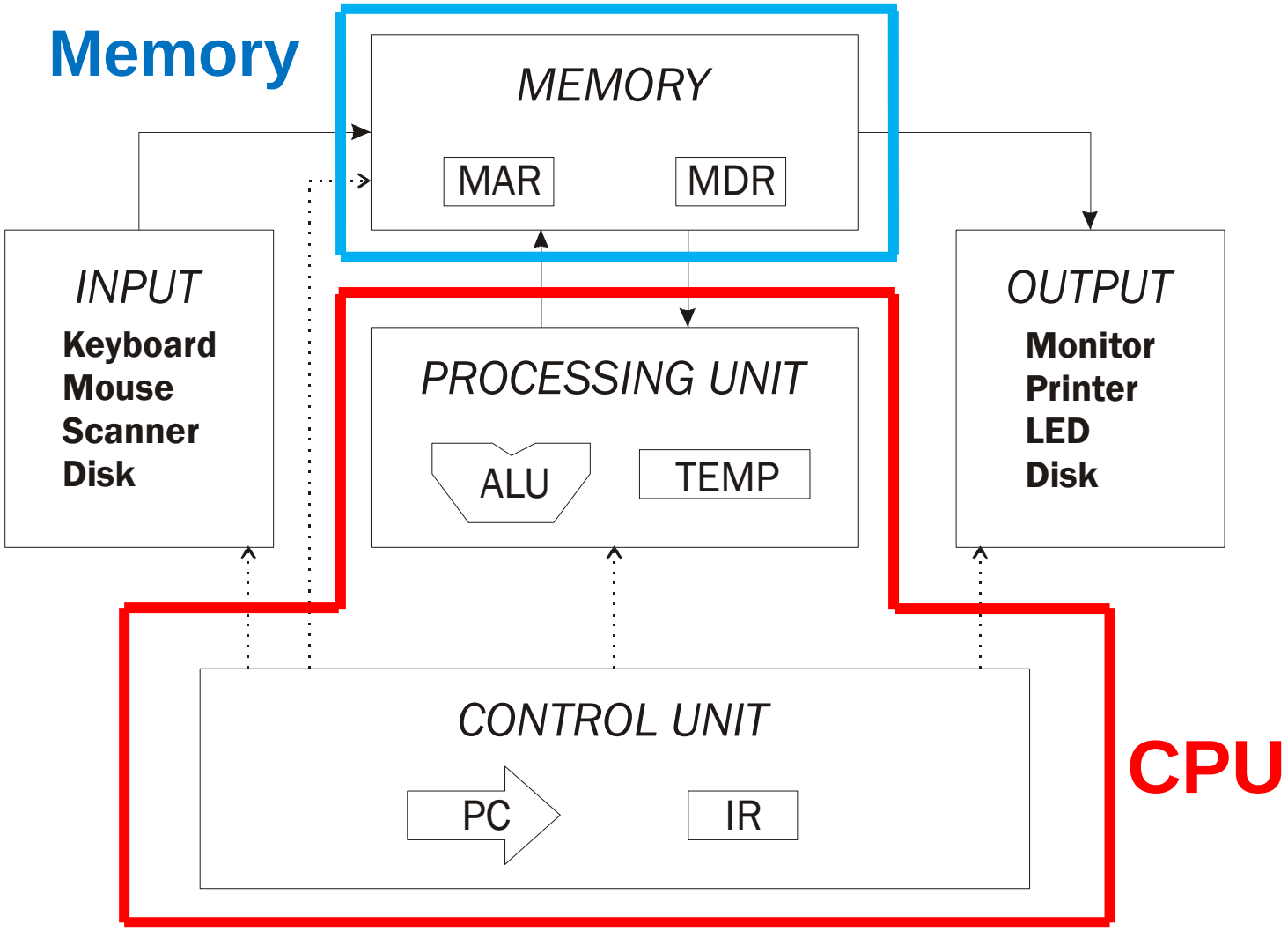
The von Neumann model

- 1943 ~ 1946: ENIAC
  - First general electronic computer
  - Hard-wired program -- settings of dials and switches
- 1944 ~ : Beginnings of EDVAC
  - Among others, includes program stored in memory
- 1945: John von Neumann
  - Wrote a report on the stored program concept
  - The basic structure proposed in the report became known as the “von Neumann machine” (or model)

The von Neumann model

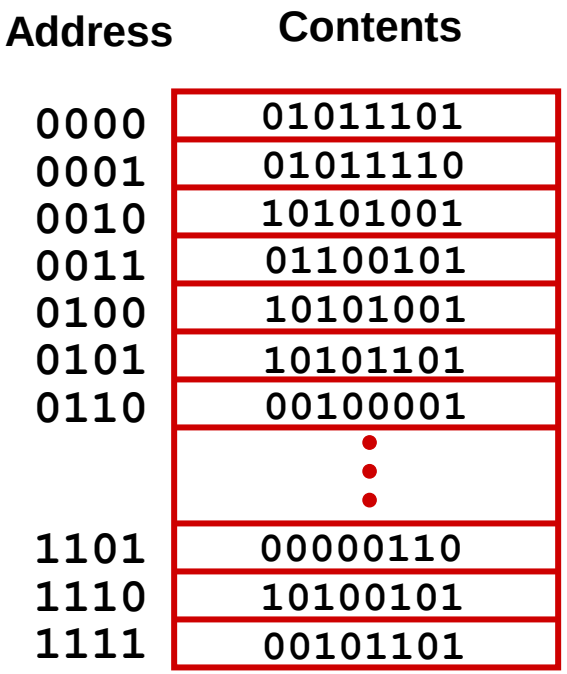


The von Neumann model



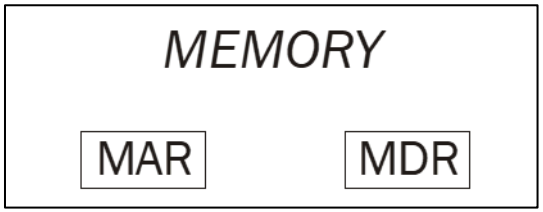
Memory

- 2k x m array of stored bits
  - **Address**
    - unique (k-bit) identifier of location
  - **Contents**
    - m-bit value stored in location
- Basic Operations:
  - **LOAD**
    - read a value from a memory location
  - **STORE**
    - write a value to a memory location



Interface to Memory

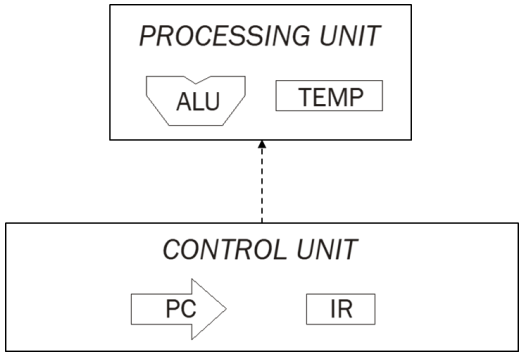
- How does processing unit get data to/from memory?
  - MAR: Memory Address Register
  - MDR: Memory Data Register



- To LOAD a location (A):
  1) Write the address (A) into the MAR
  2) Send a "read" signal to the memory
  3) Read the data from MDR

- To STORE a value (X) to a location (A):
  1) Write the data (X) to the MDR
  2) Write the address (A) into the MAR
  3) Send a "write" signal to the memory

Processing Unit and Control Unit



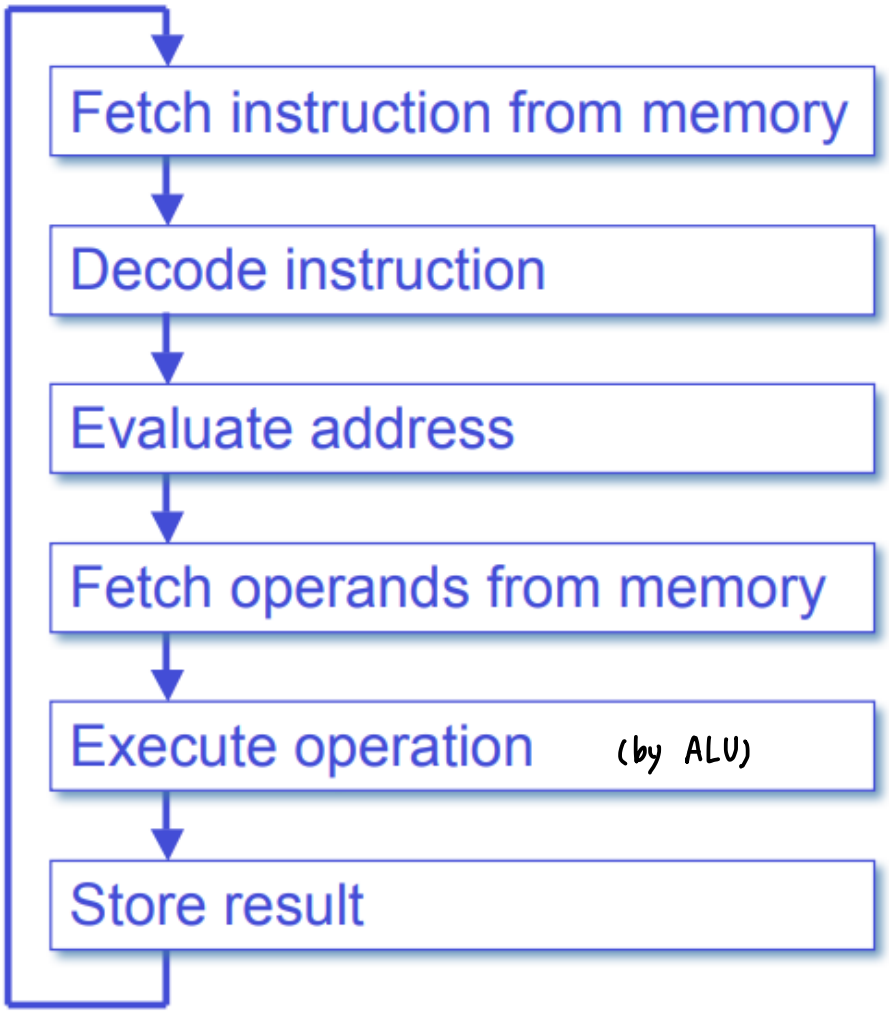
❒ Processing Unit

- **ALU = Arithmetic and Logic Unit**
  - could have many functional units
  - some of them have special-purpose (multiply, square root, …)
  - LC-3 (Little Computer) performs ADD, AND, NOT
- **TEMP (registers)**
  - Small, temporary storage (operands and results)
  - LC-3 has eight registers (R0, …, R7), each 16 bits wide

❒ Control Unit

- **Instruction Register (IR)**
  - contains the current instruction
- **Program Counter (PC)**
  - contains the address of the next instruction to be executed

Instruction Processing



II. Program Execution

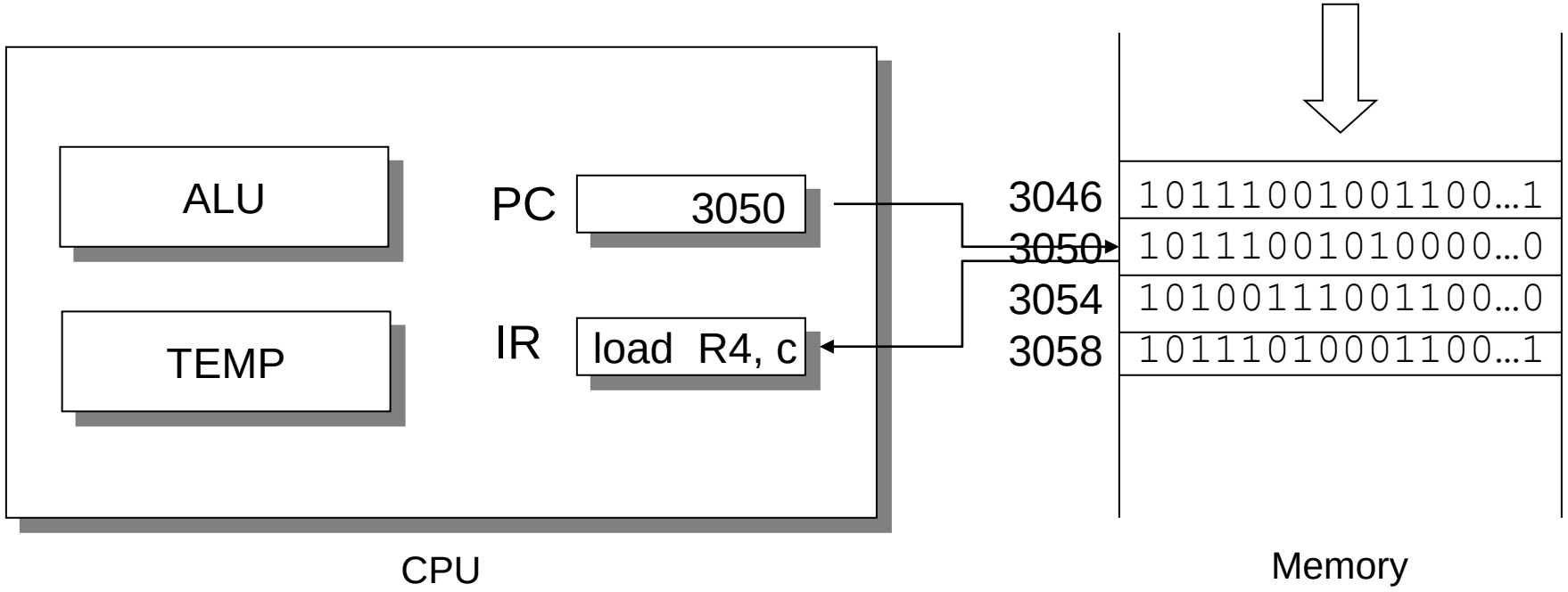
The Concept of Programming

- We can tell the CPU through machine language
  - CPU can understand and execute only instructions
- An instruction is a command given to a processor
  - Each instruction is a sequence of 0s and 1s
  - Physical operations such as load, store, add, sub, mul, …
- "Programming" means
  - Constructing a sequence of instructions
  - The result is called "program"

Assembly Programming

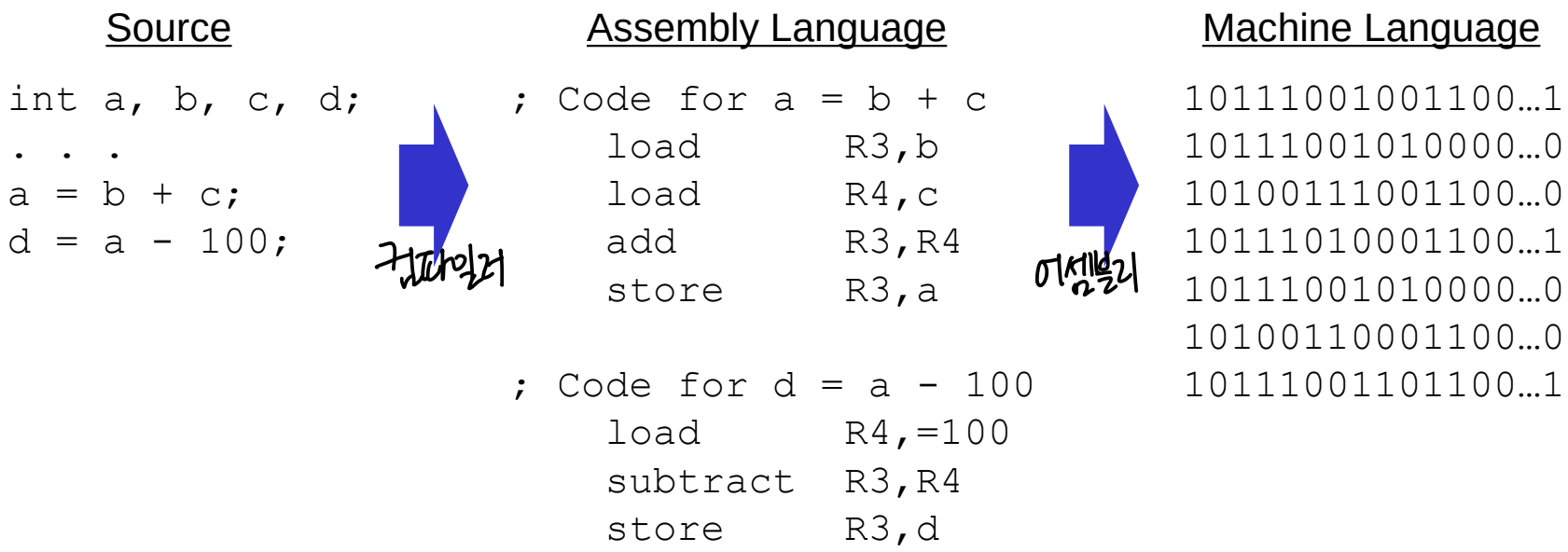
- Programming using symbolic assembly instructions
  - One-to-one correspondence with binary machine instructions

```
load   R3,b
load   R4,c
add    R3,R4
store  R3,a
```



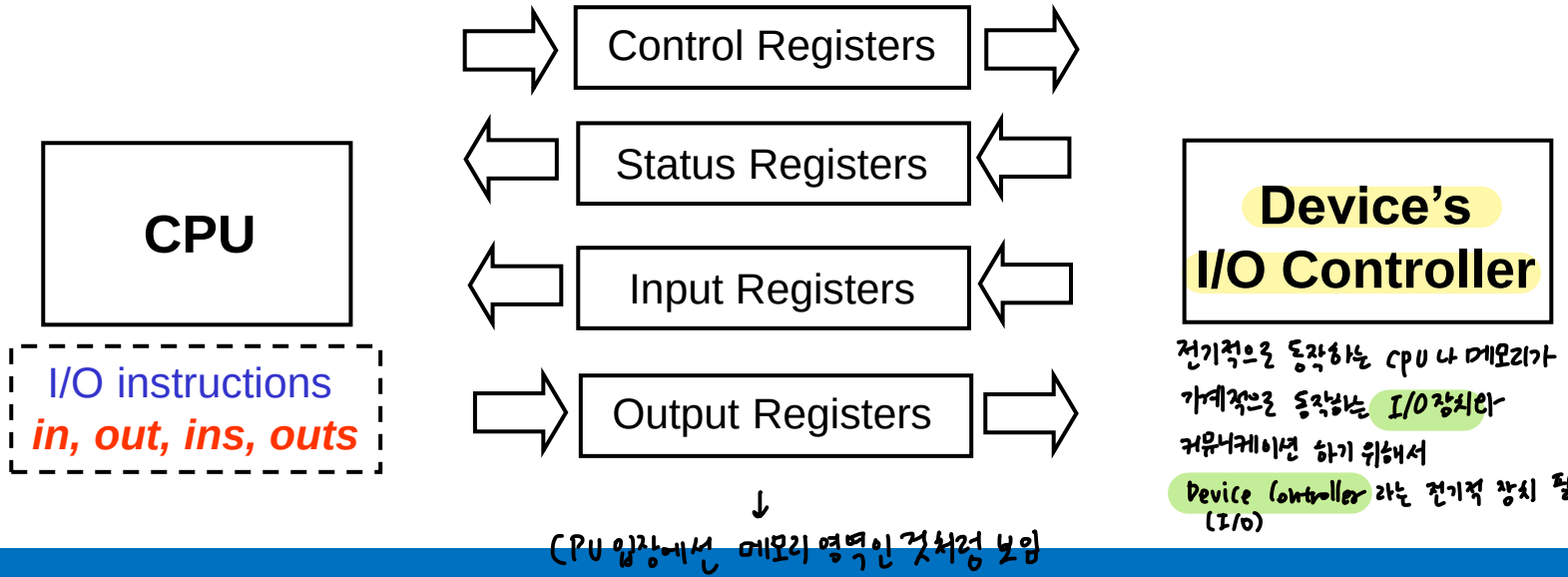
Program and Languages

- **Assembly programming is difficult and tedious**
  - **Use higher level languages**
    - C, C++, Java
  - **Compilation**
    - High-level language → Assembly code → Machine instructions



Programming I/O Devices

- Each I/O device has a controller (or interface)
- CPU communicates with the I/O controller
  - Control register: write commands
  - Status register: read the device's internal state
  - Input register: fetch data
  - Output register: write data



thank you!

Special-Purpose Processors

❒ GPUs - graphical processing units

- Efficient computation on arrays using Single-Instruction Multiple Data (SIMD)
- Numeric processing, physics simulations, games, large spreadsheet computation
- Parallel computing standards: CUDA, OpenCL

Radeon HD 7970M (image: diit.cz)
28nm, OpenGL, DirectX, 2.2 TFLOPS, 75W

❒ DSPs - digital signal processors

- Streaming audio or video ('codecs'), encryption

(image: ti.fleishman.de)

Special-Purpose Processors

- **SoC - system on chip**
  - **Components like DSP, GPU, main memory, cache, and I/O controllers can all go onto a single chip (or "die")**
  - **May include analog and mixed-signal components**
  - **Often used in embedded applications**

A8X SoC for iPad Air 2:
Tri-core ARM v8 CPU
Eight-core PowerVR GPU
(image: anandtech.com)