05.08.20 12:34

CSCI 150
Introduction to Digital and Computer System Design
Lecture 6: Memory I

Jetic Gū

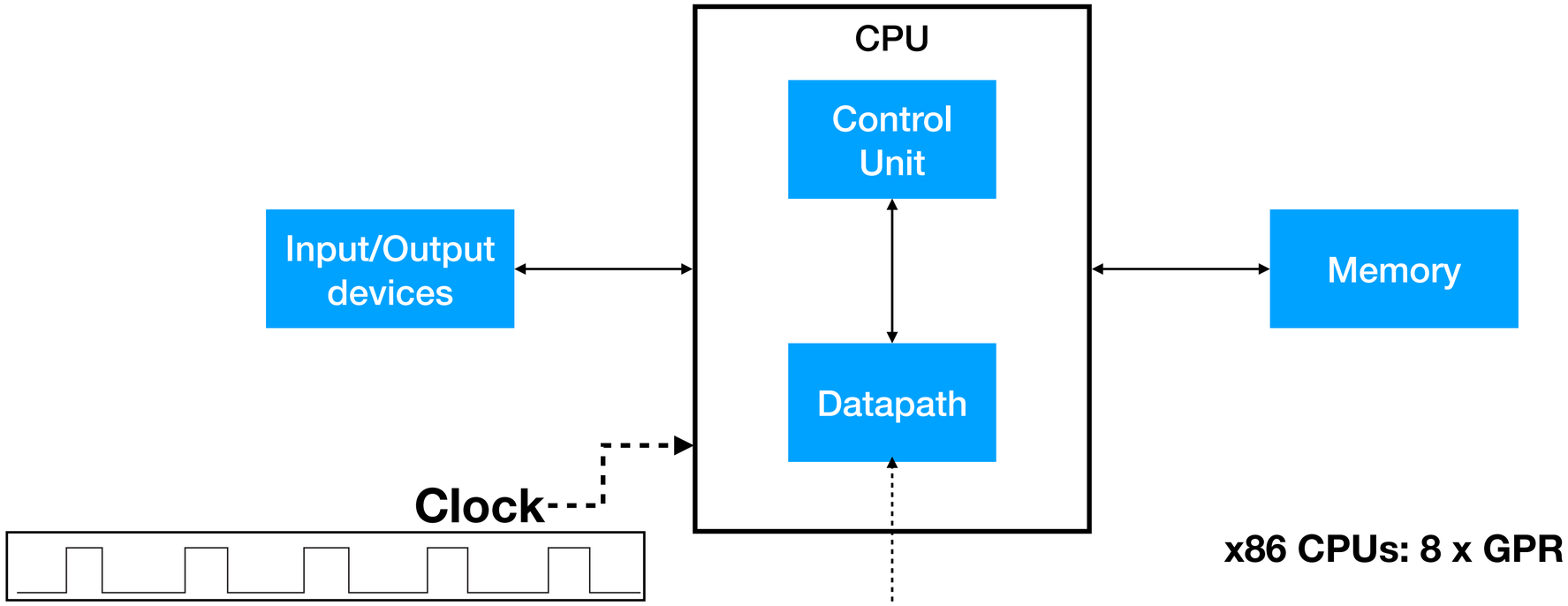
2020 Summer Semester (S2)

Overview

- Focus: Fundamentals of Complex Digital Circuit Design
- Architecture: von Neumann
- Textbook v4: Ch8 8.1, 8.2, 8.3; v5: Ch7 7.1, 7.2, 7.3
- Core Ideas:
    1. Memory Definition
    2. Read Only Memory
    3. Random Access Memory

P0
Review

Computer



x86 CPUs: 8 x GPR

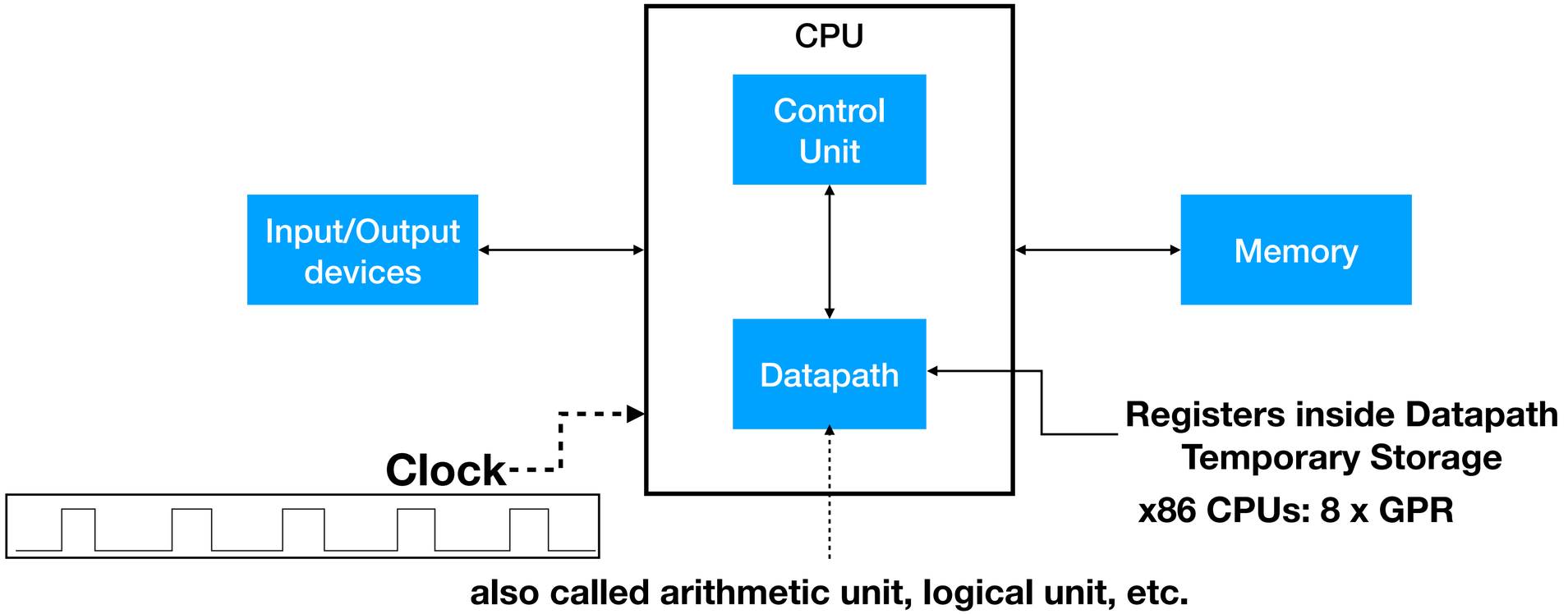
also called arithmetic unit, logical unit, etc.

1. Von Neumann Architecture

Review

P0
Review

Computer



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P0
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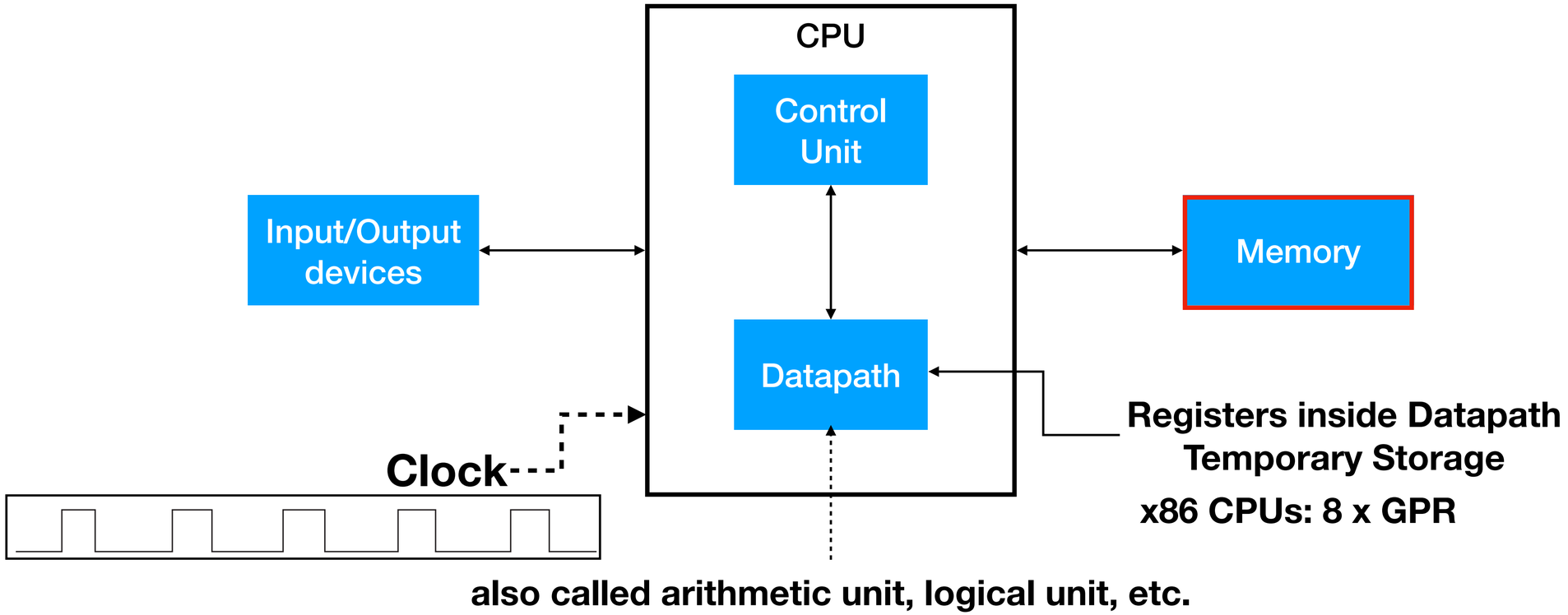

1. Von Neumann Architecture

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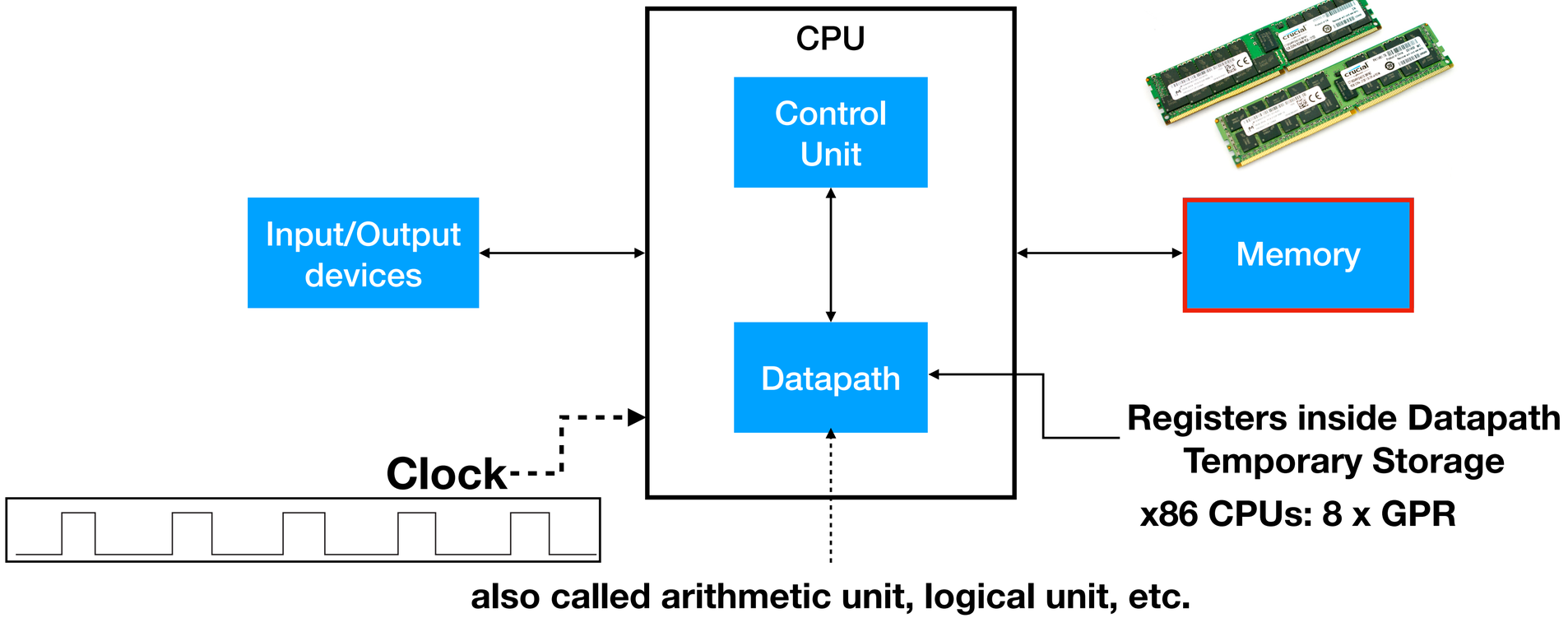


1. Von Neumann Architecture

Review

P1
Definition

Memory Definition

Wait… do I have to remember that?

Summary

P1
Definition

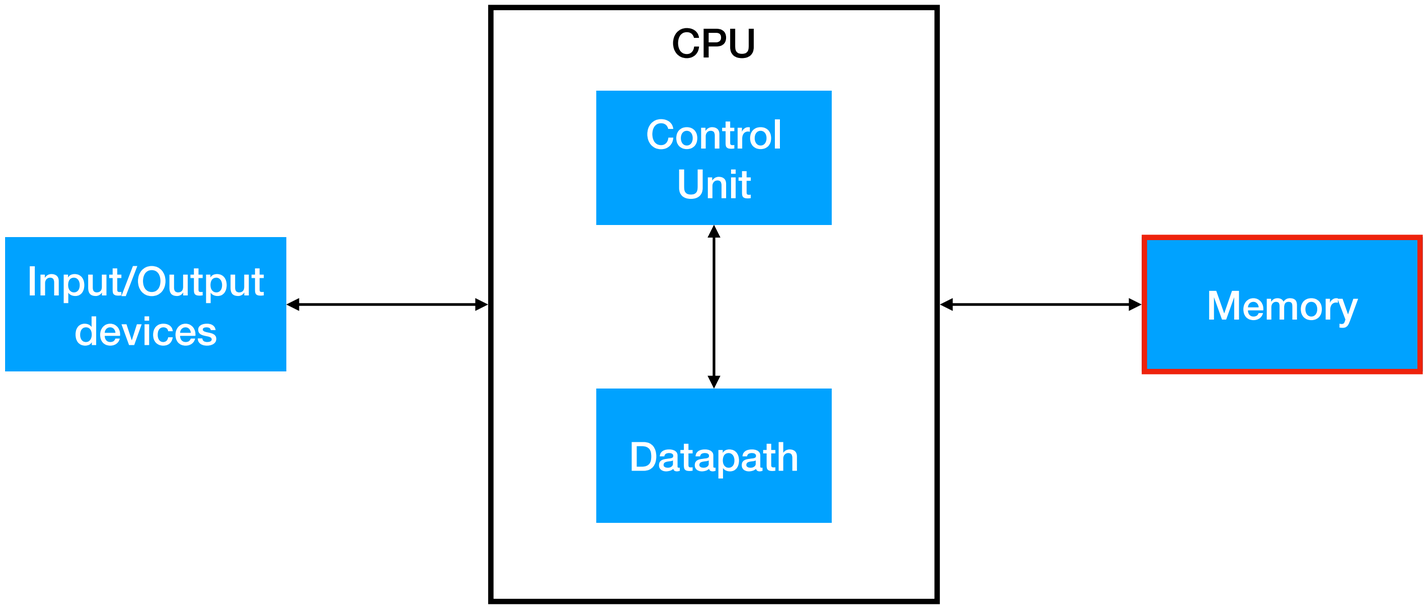
Memory Definition

- A **collection of cells** capable of storing binary information
- providing **temporary** or **permanent** storage for **substantial amounts** of binary information
  - **Substantial**: much much much more than registers in a CPU
  - Temporary: e.g. DDR4 memory sticks
  - Permanent: e.g. IO devices (SSD, HDD), ROM

Concept

P1
Definition

Computers In Theory



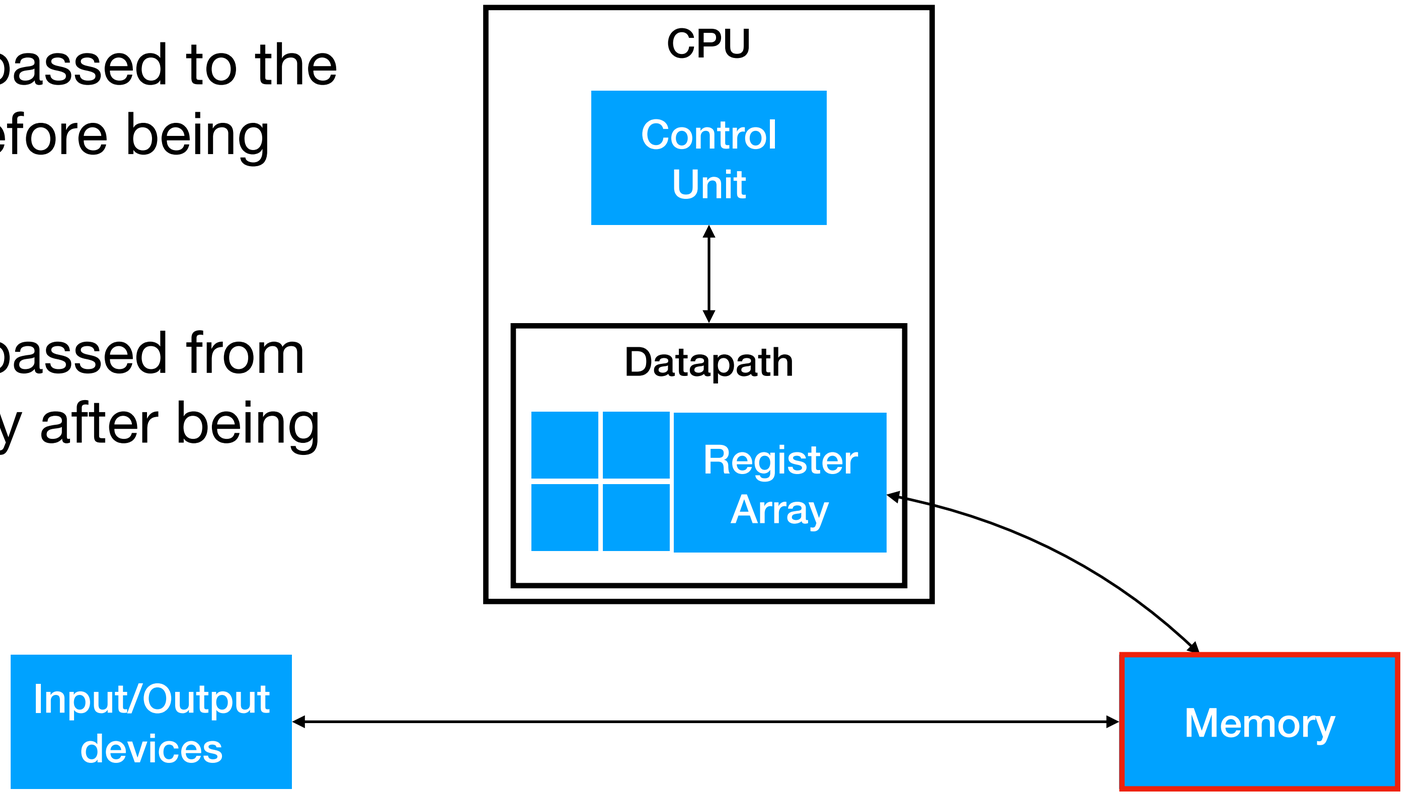
Concept

1. Von Neumann Architecture

P1
Definition

Computers In Reality

- IO data is passed to the memory before being processed
- IO data is passed from the memory after being processed



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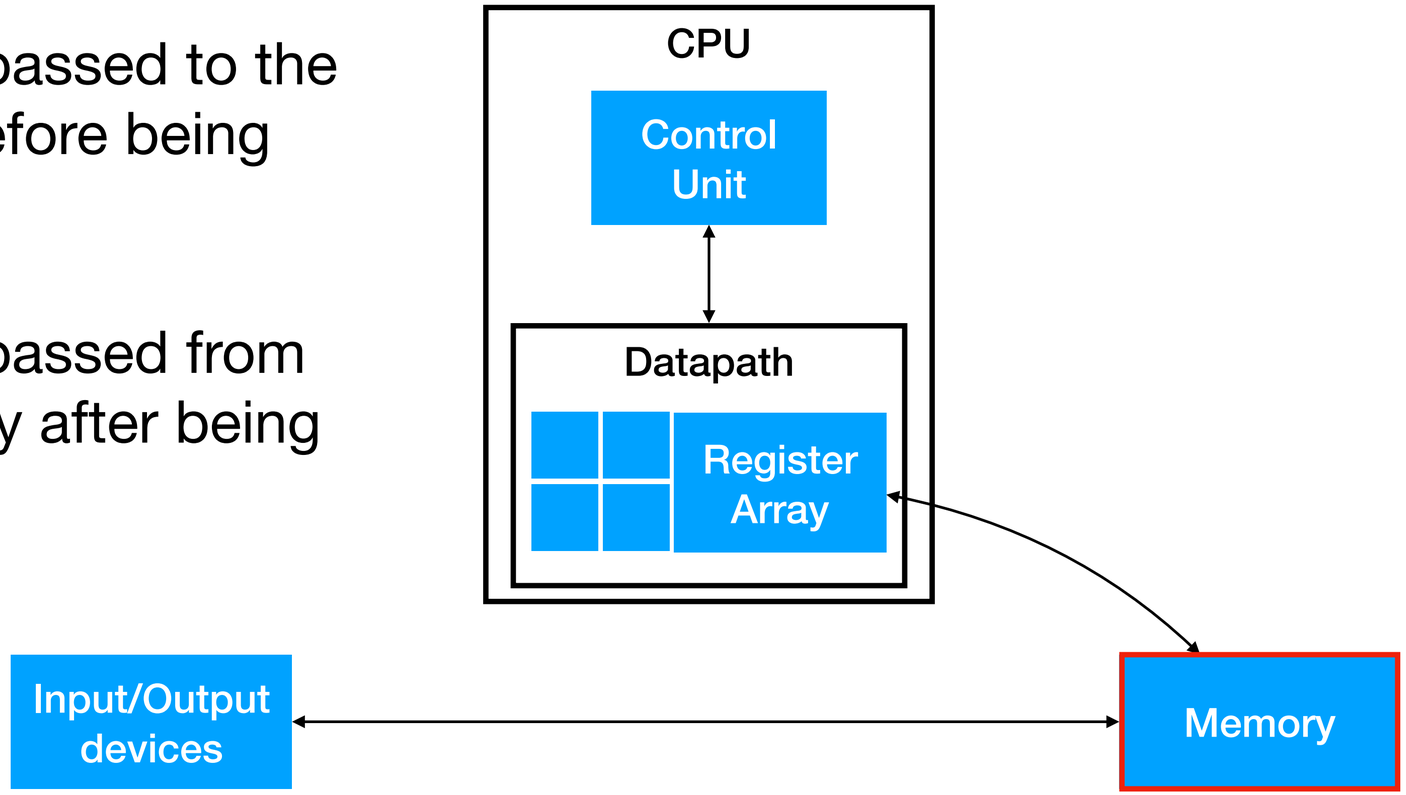

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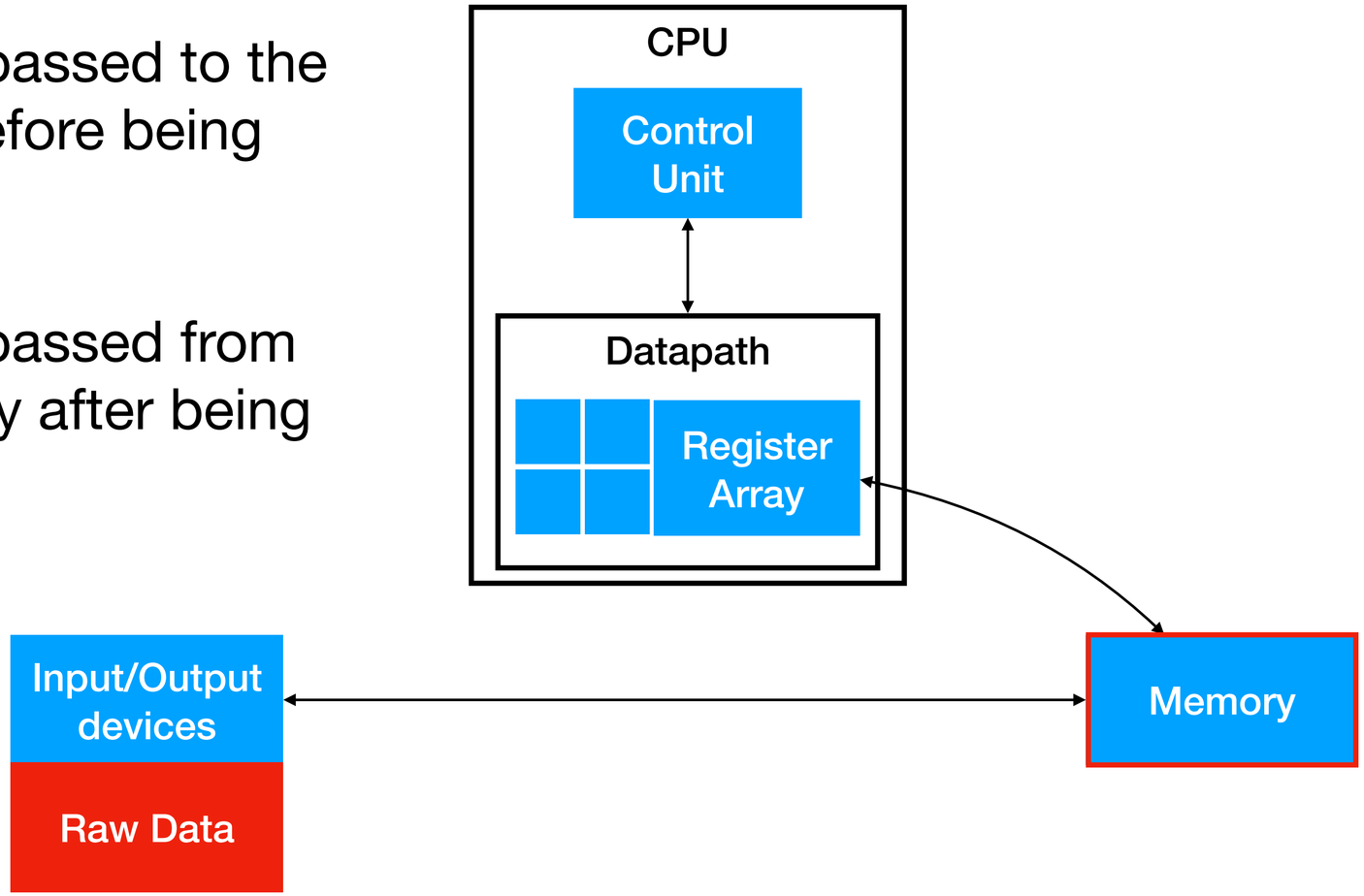

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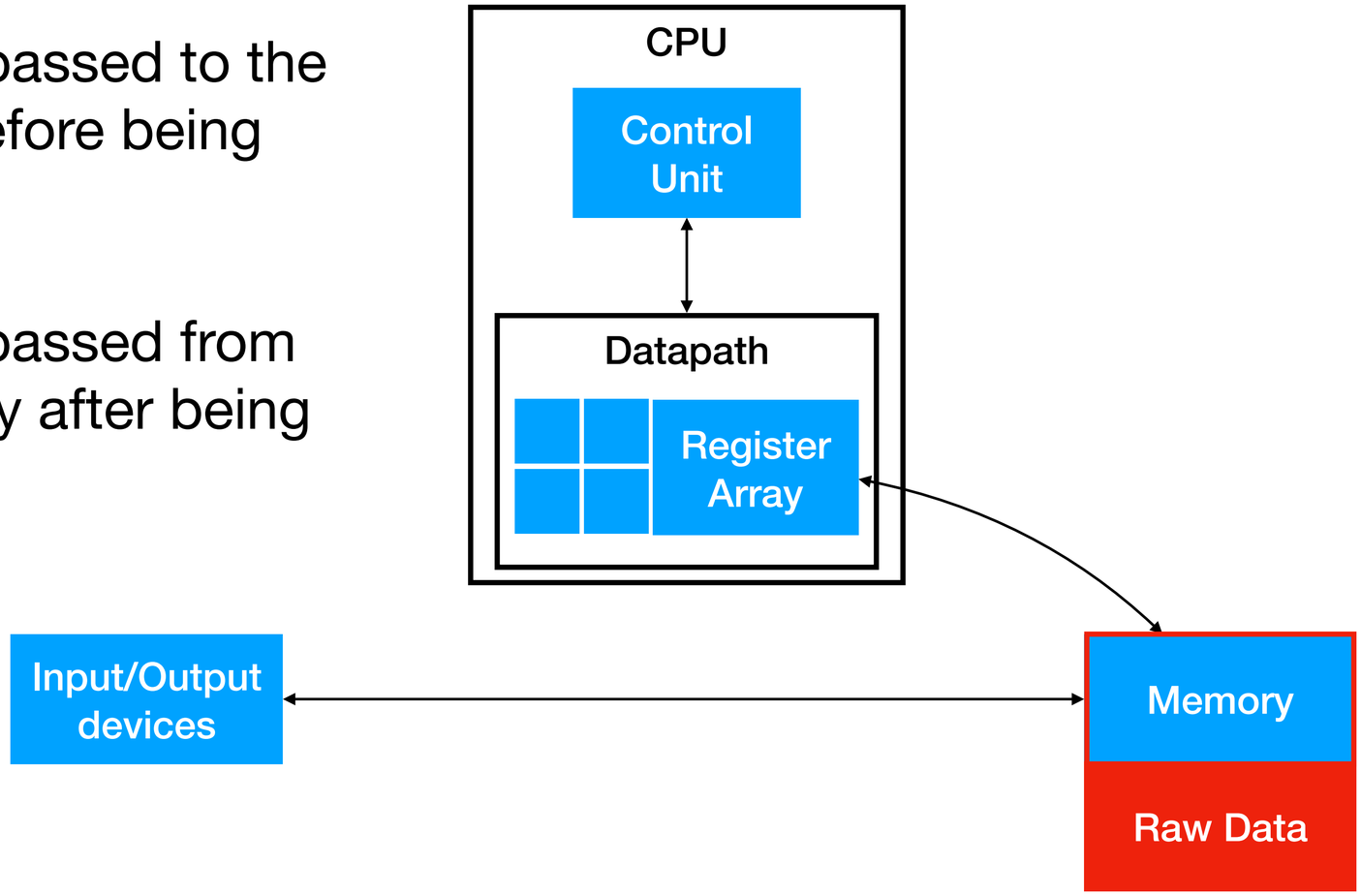

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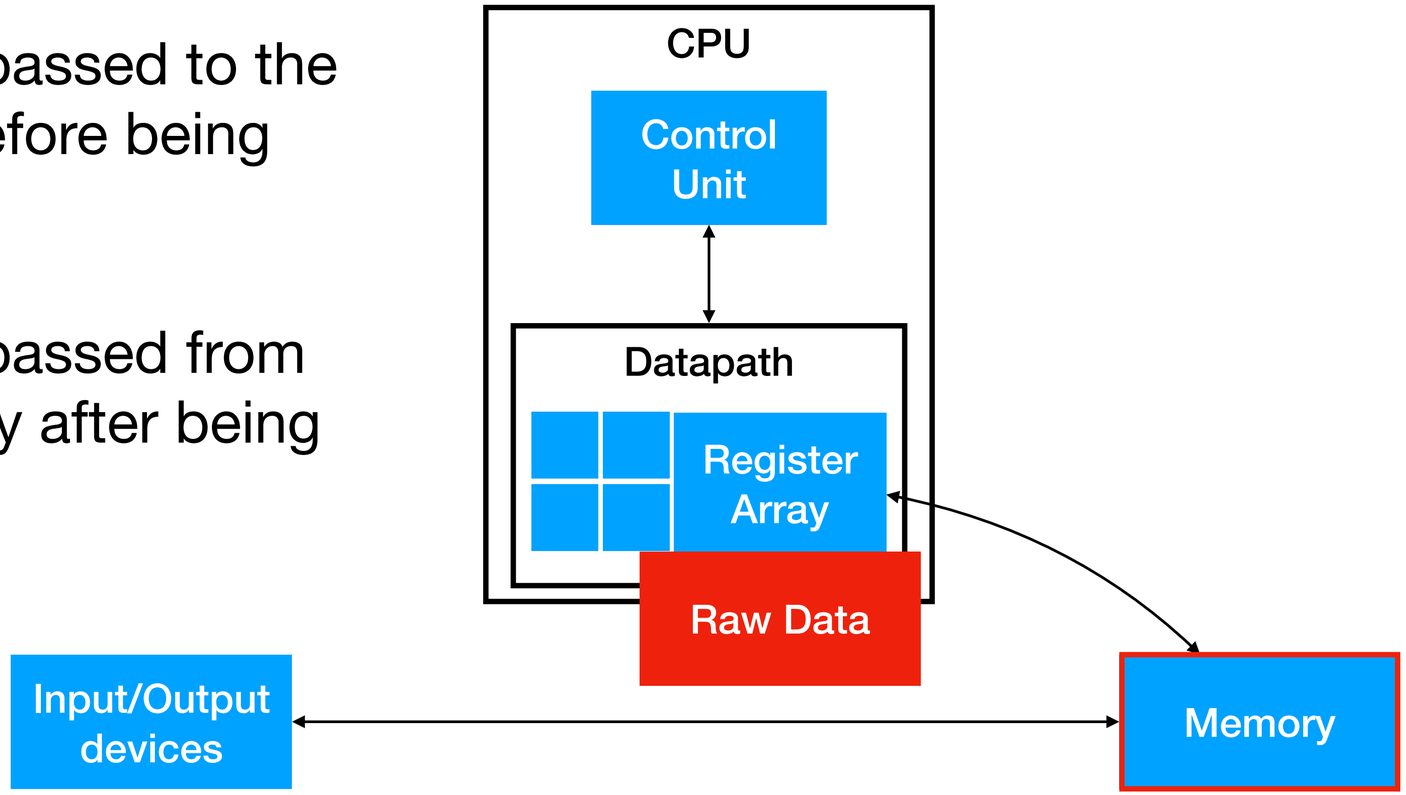

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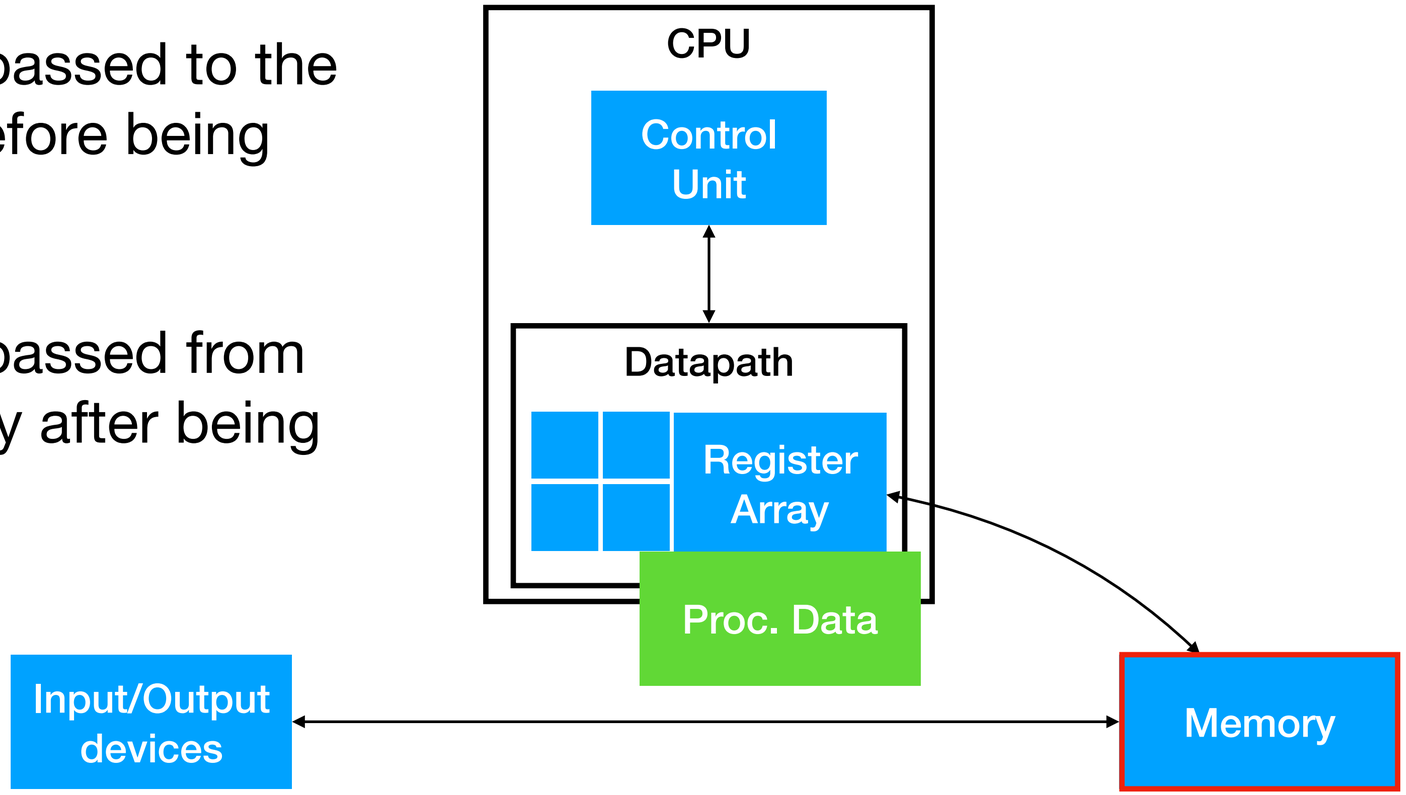

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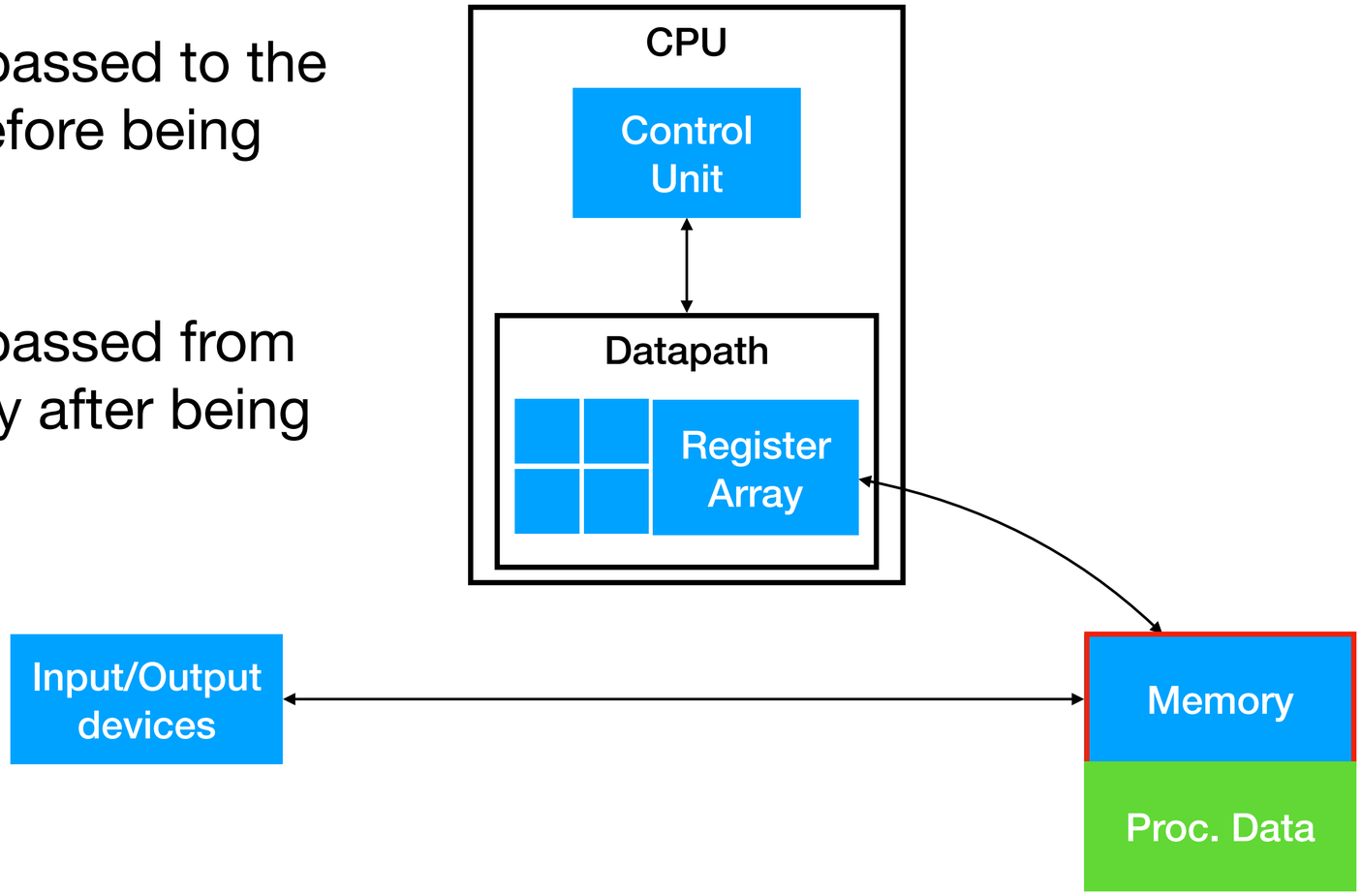

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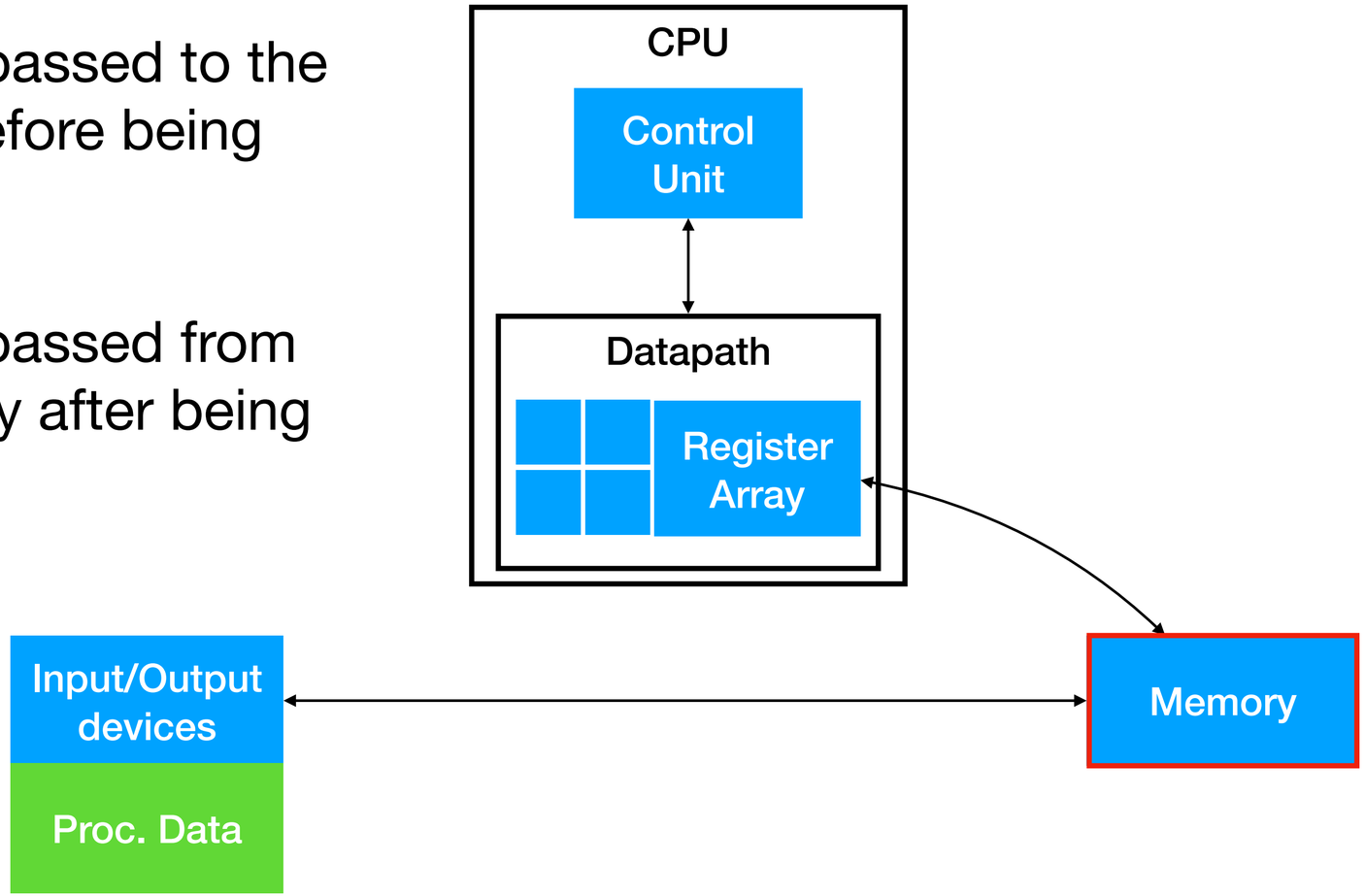

Concept

P1
Definition

2 Types of Memories

- RAM (Random Access Memory)
  Memory Read Operation: retrieves information from memory
  Memory Write Operation: accepts new information for storage

  - Volatile: require power for keeping its content 

- ROM (Read Only Memory)
  Memory Read Operation: retrieves information from memory

  - Non-volatile: might not need constant power to keep its content 

- Why do we need ROMs?

Concept

P2
ROM

Read Only Memory

Remember CD-ROMs?

Summary

The Many Types of ROMs

- CD-ROM
- DVD-ROM
- Firmware ROM

- Essentially, devices that stores information that cannot be normally erased/ rewritten, and usually are non-volatile

Concept

ROM Abstraction

- Storage: $2^n \times m$, 2^n words, each m-bits
  (usually $m = 8$, which makes a word=a byte)
  - 32-bit processor, $n = 32$, supports 2^{32} bytes in memory ~ 4GB
- Input: address in n-bit binary
- Output: m-bits of stored information

Concept

ROM Abstraction

- 8-bit processor
  Each address is in 8-bit, total of 256 different addresses

Example

ROM Abstraction

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= **00001010**

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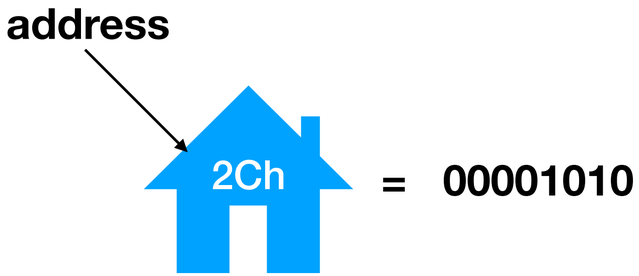

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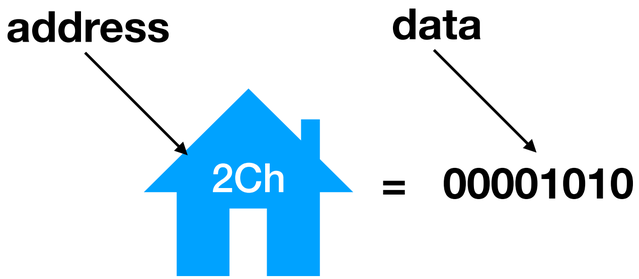

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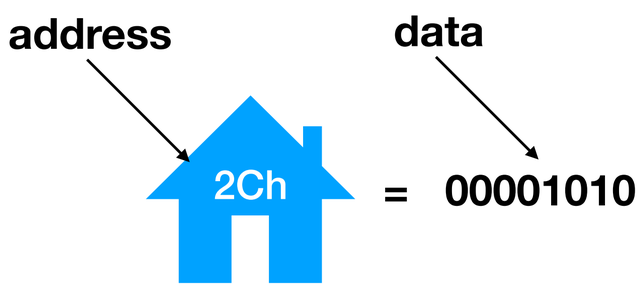

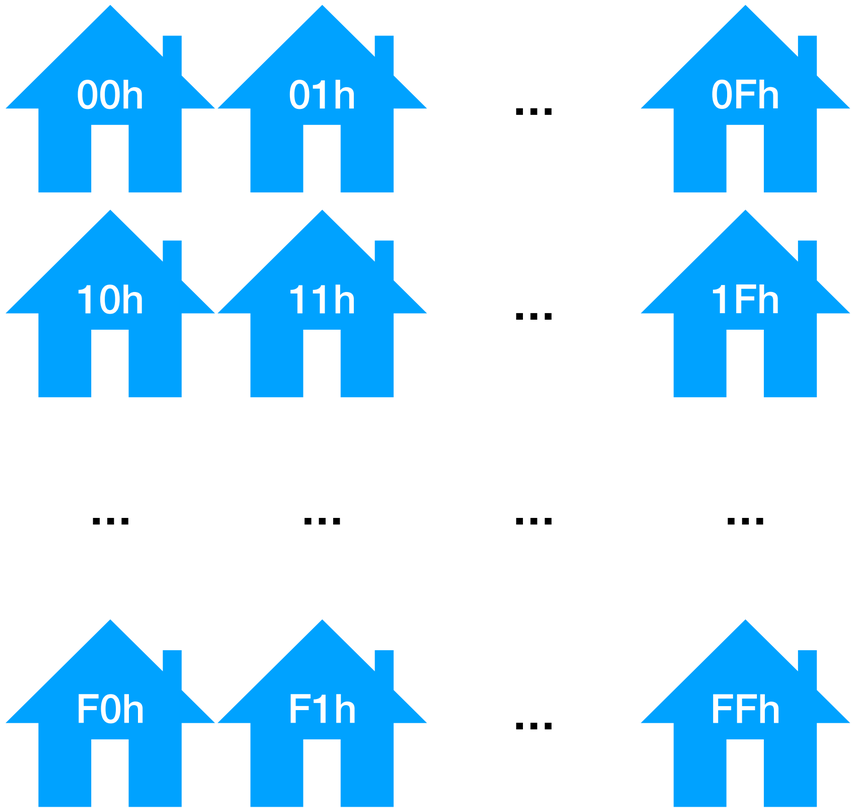

Example

P2
ROM

Question

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- What is the maximum supported memory size for a CPU with 8-bit address space, 1 byte per word?

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  - Ans: $2^8 \times 1 = 256$

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- What is the maximum supported memory size for a CPU with 8-bit address space, 1 byte per word?
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  - Ans: $2^{16} \times 1 = 65536$
- What is the maximum supported memory size for a CPU with 16-bit address space, 2 bytes per word?
  - Ans: $2^{16} \times 2 = 131072$

P2
ROM

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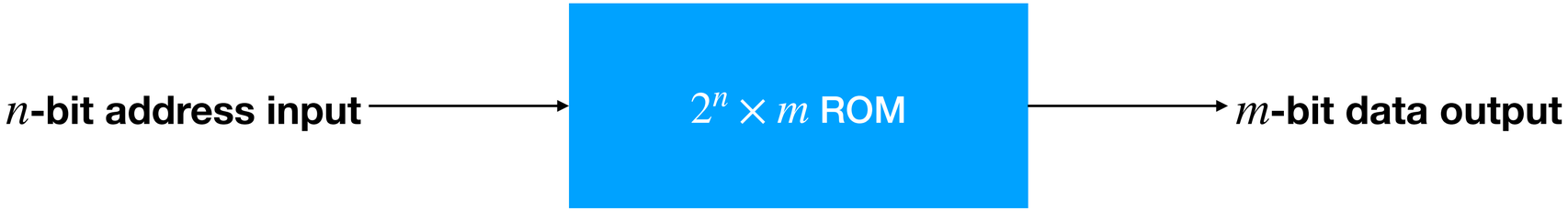
- 64-bit CPUs have 64-bit memory space, each word 8-bits
- What is the maximum supported memory size for a 64-bit CPU?
  - Ans: $2^{64} \times 1 = 18{,}446{,}744{,}073{,}709{,}551{,}616$ = 17 million Terabytes (16 exabytes)

Question

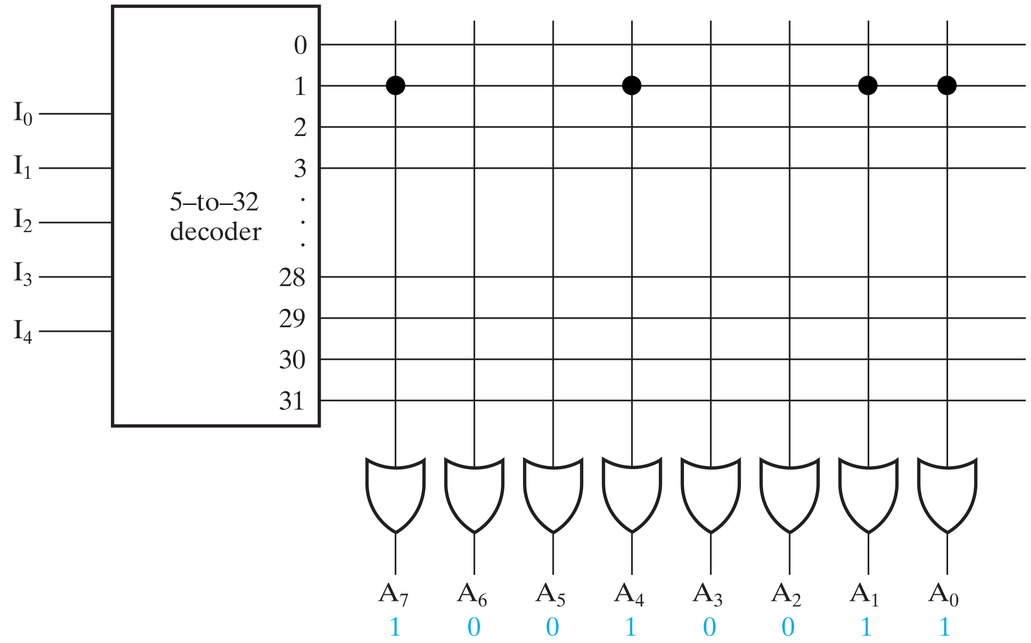
P2
ROM

ROM Abstraction



Concept

ROM Implementation Example



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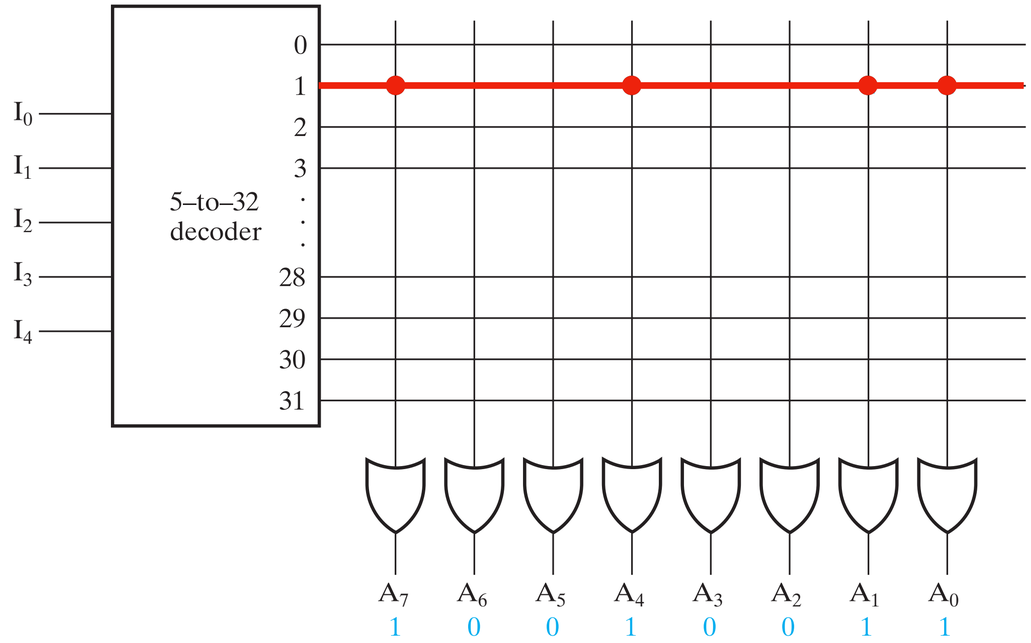

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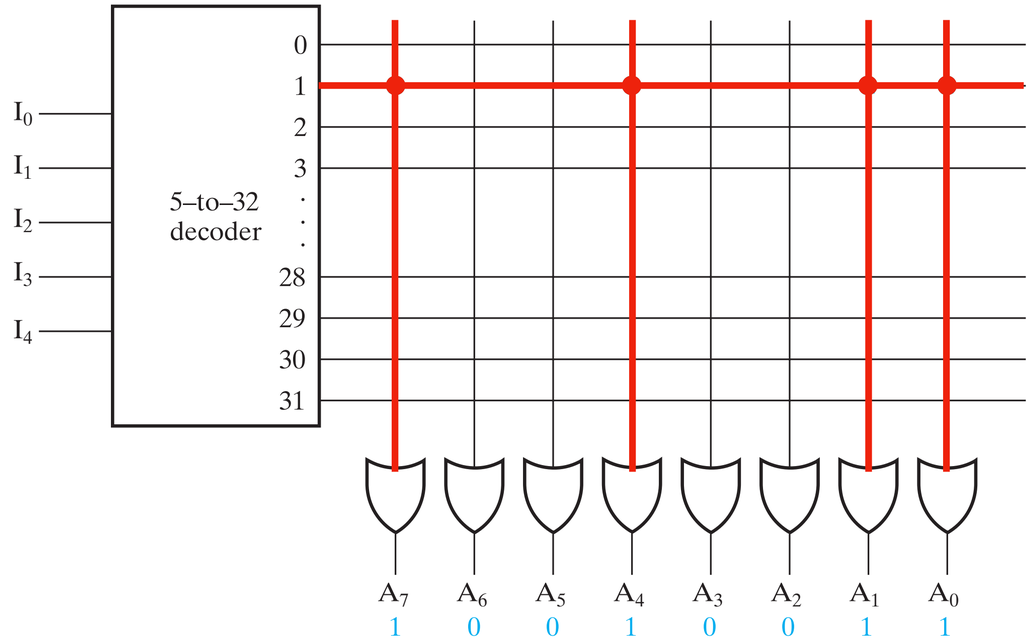

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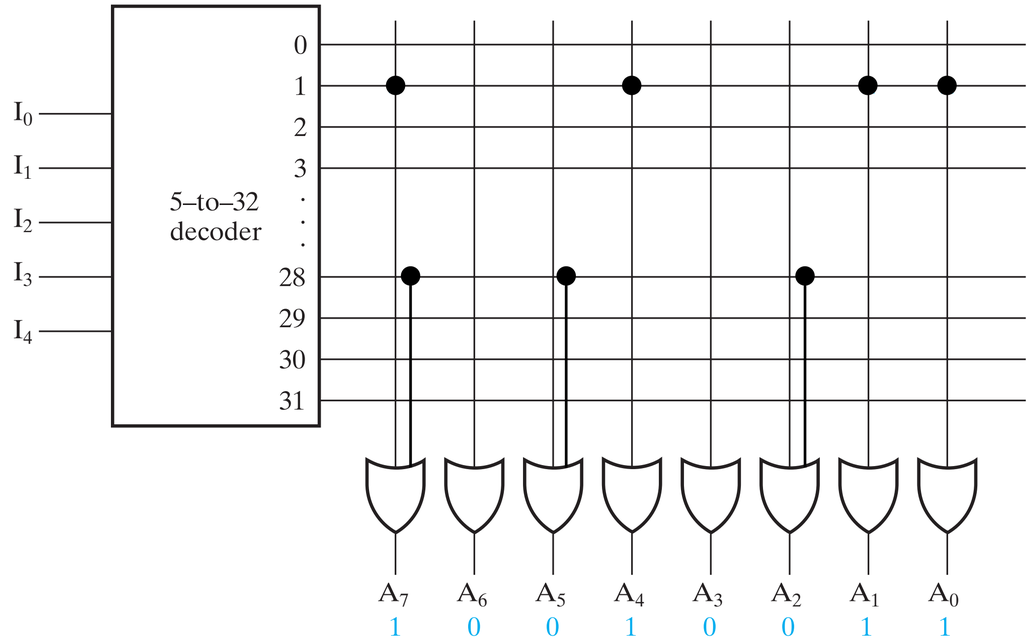

- This ROM has value `10010011` at address `01h`;

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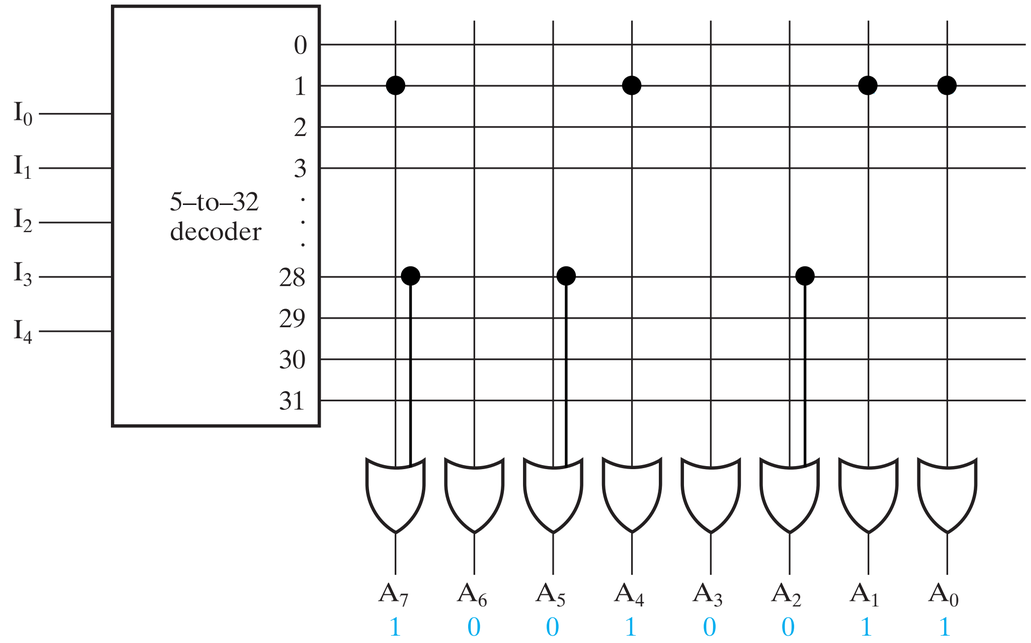

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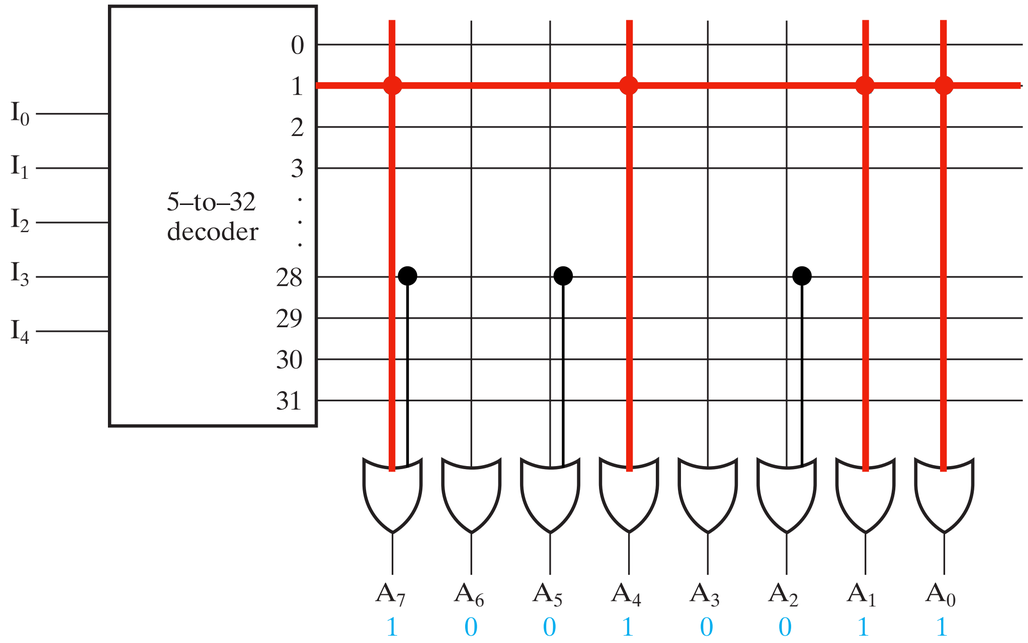

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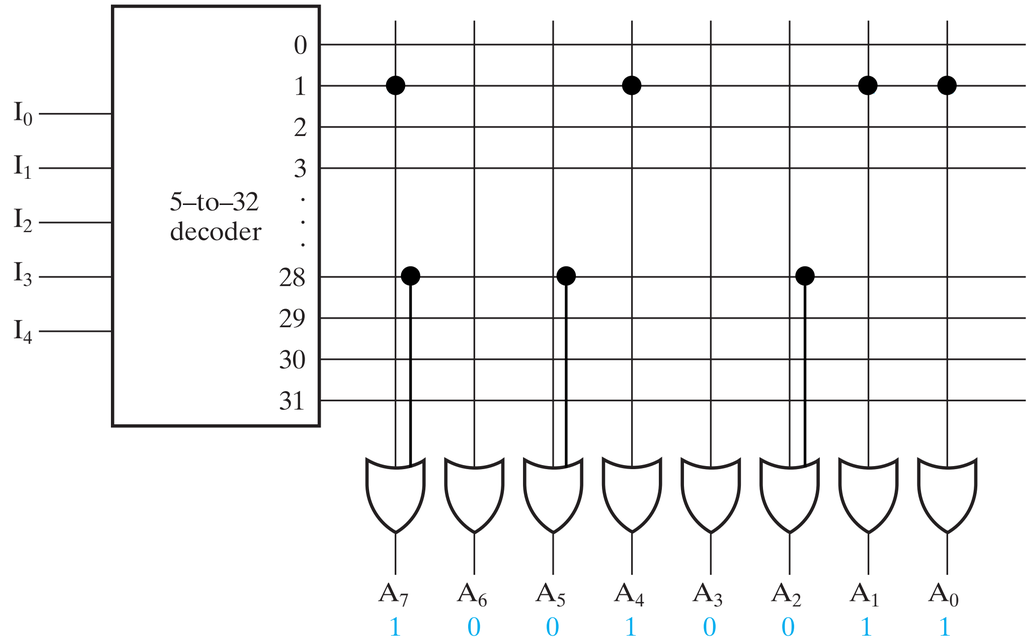

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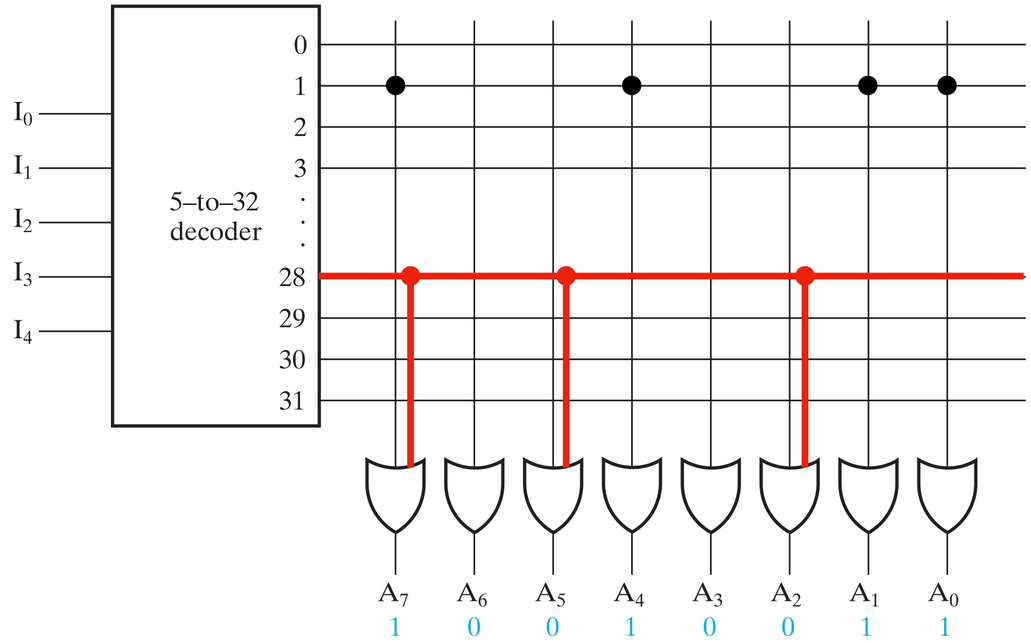

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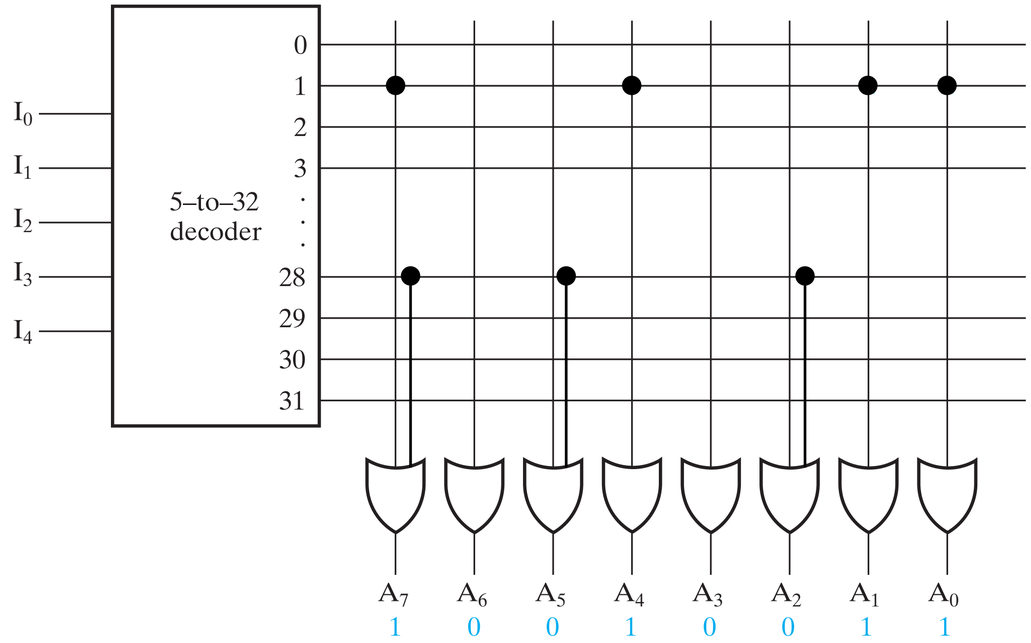

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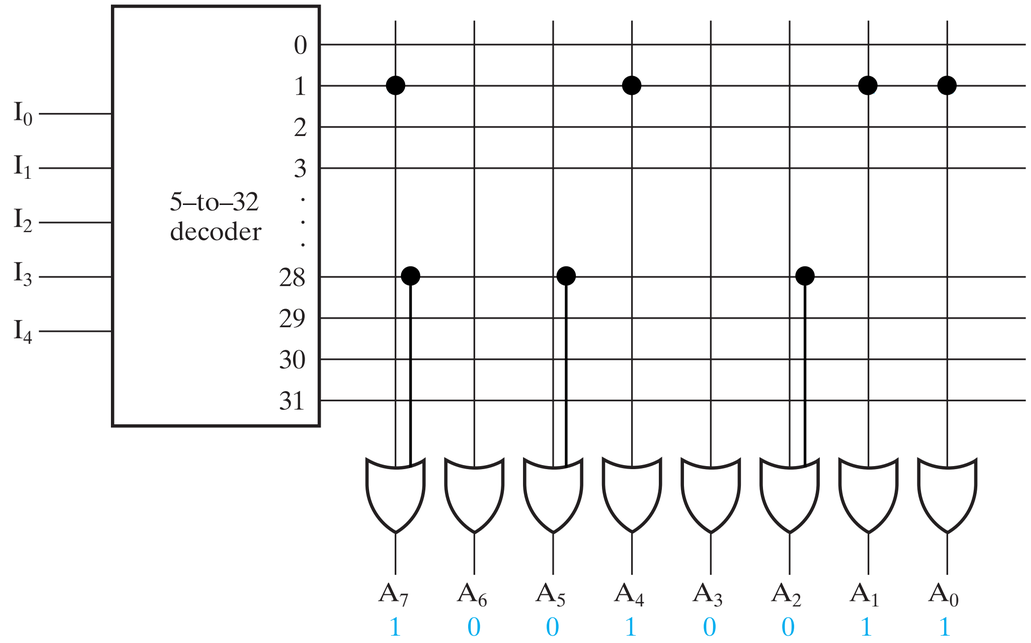

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- In reality, these wiring are done with programmable technology

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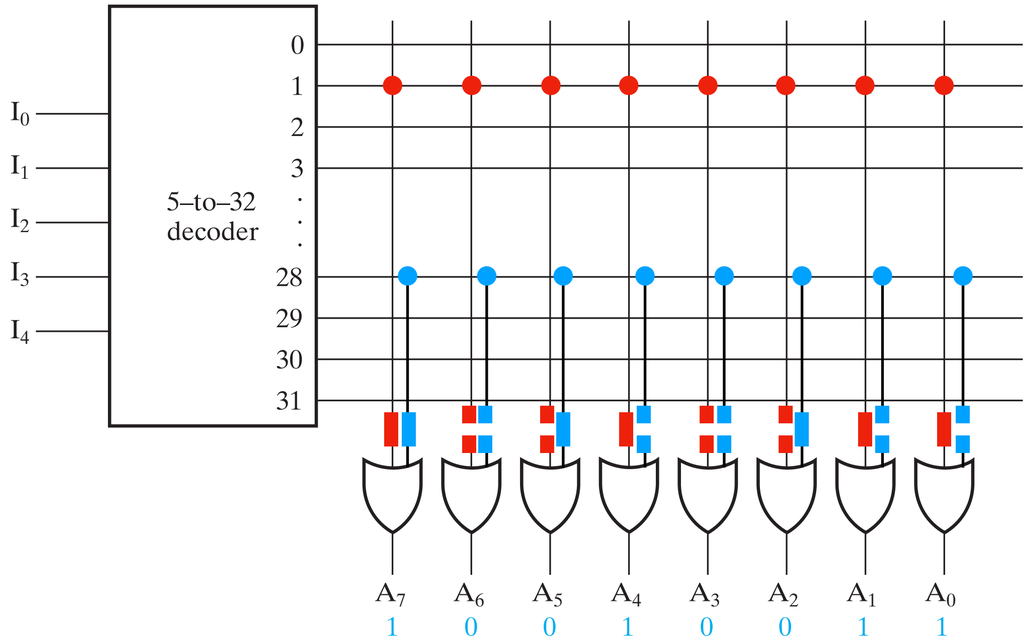

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P2
ROM

Reasons for choosing ROM

Concept

P2
ROM

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- Originally proposed as unhackable storage devices
  Fixed internal data, cannot be hijacked through software

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- Fun fact: early **SSD**s were using Flash Memory technology, an **Electrically Erasable ROM** (like in the previous slide), which is why they were so expensive

Concept

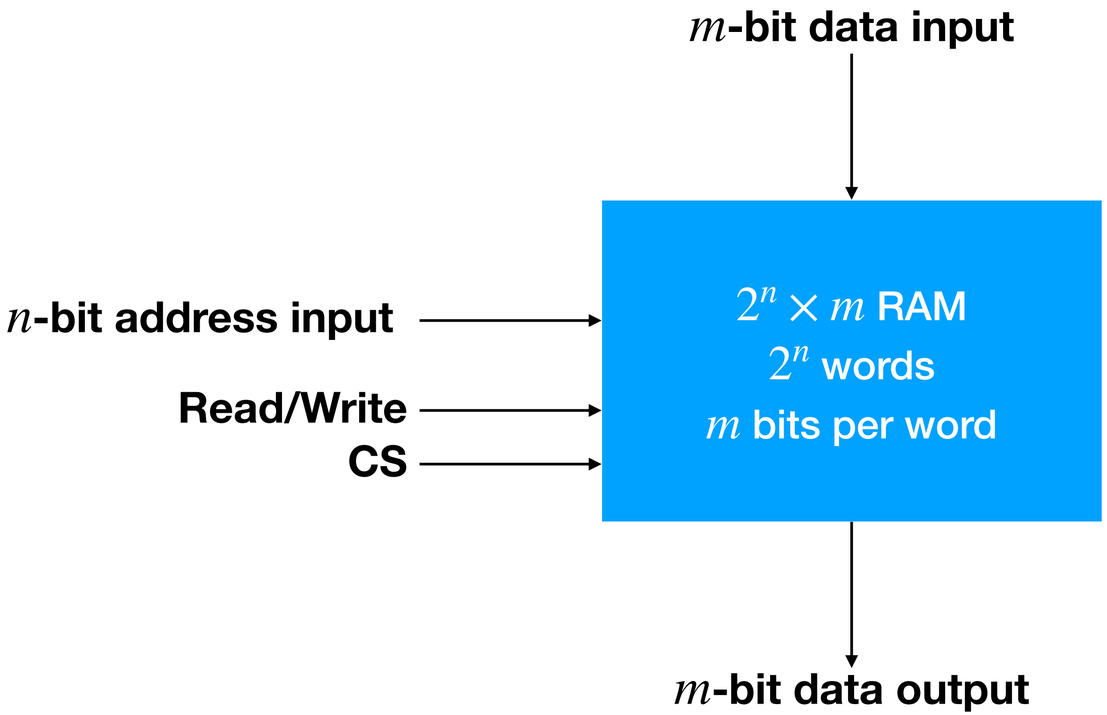
P3
RAM

Random Access Memory

Now supporting `Write` in all participating memory sticks

Summary

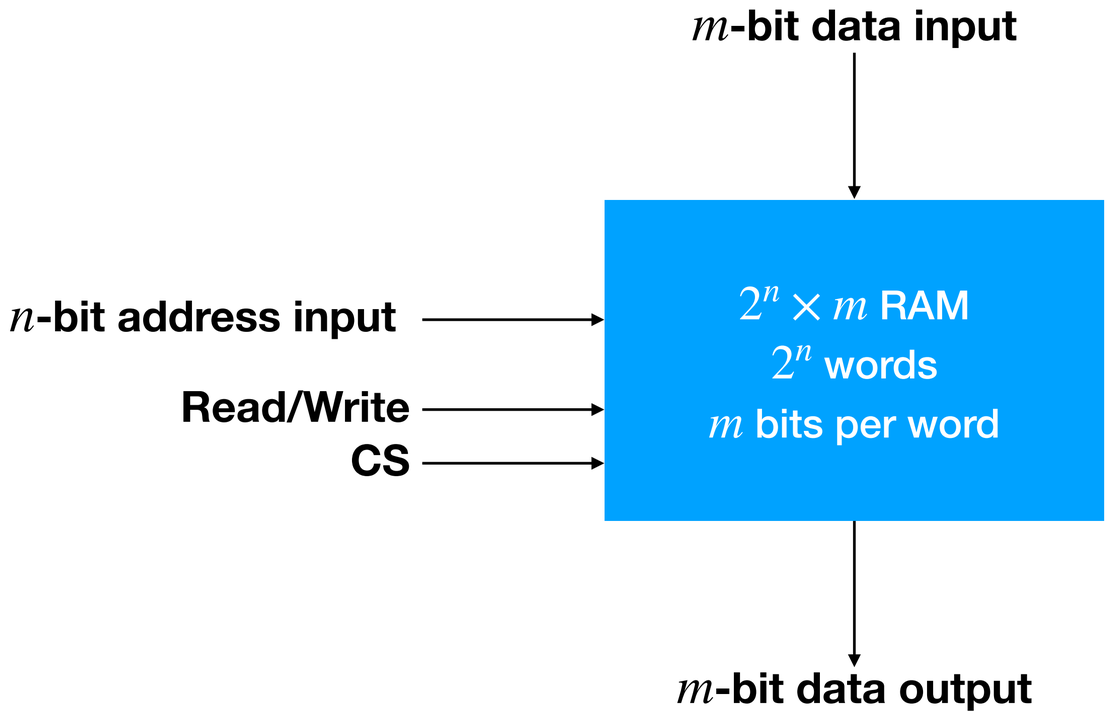
RAM Abstraction



Chip Select CS	Read/$\overline{\text{Write}}$ R/$\overline{\text{W}}$	Memory Operation
0	×	None
1	0	Write to selected word
1	1	Read from selected word

Concept

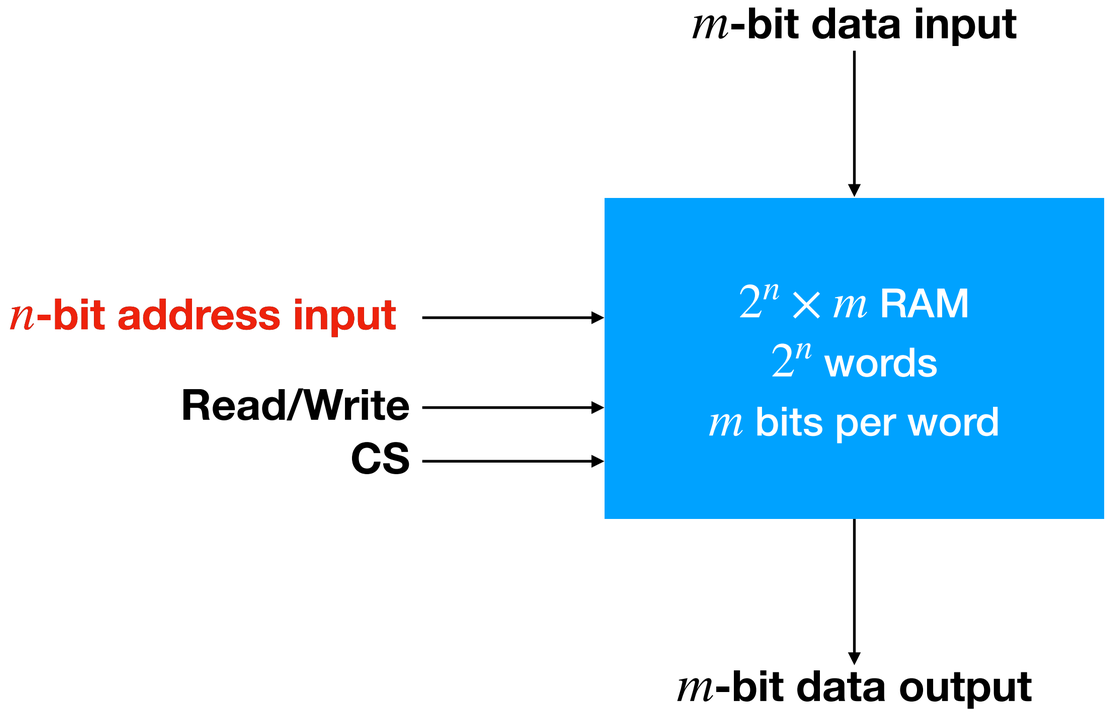
Steps for `Write`



Demo

Steps for `Write`

1. Apply the address of the desired word to the address lines



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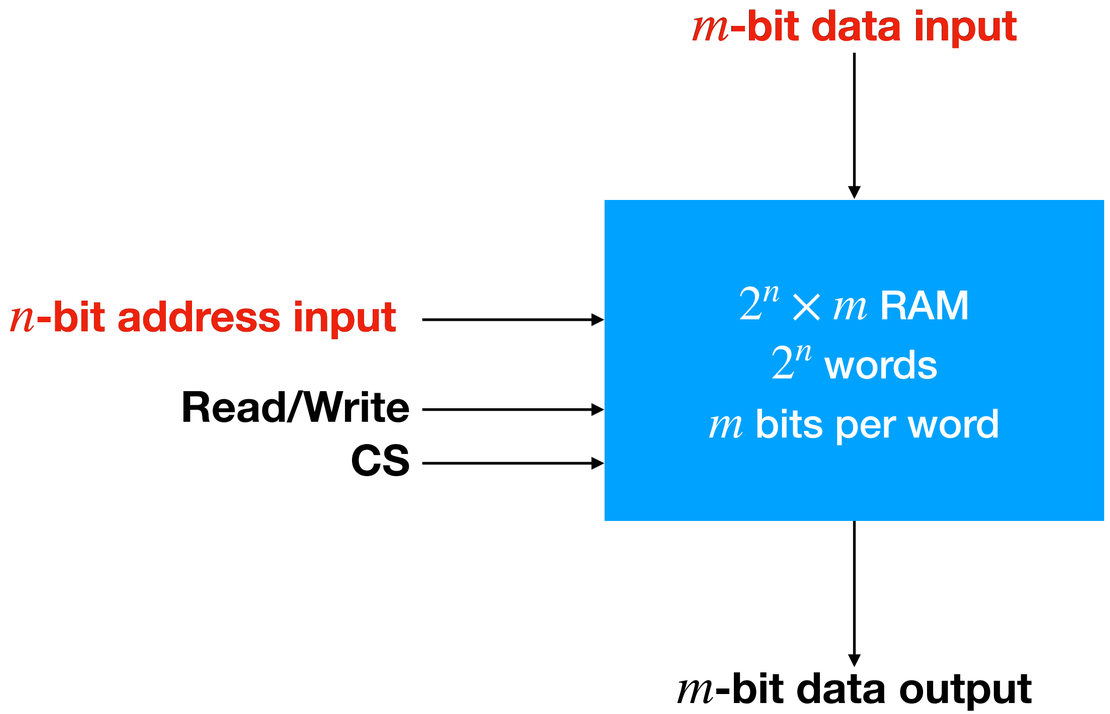

Demo

Steps for `Write`

1. Apply the address of the desired word to the address lines
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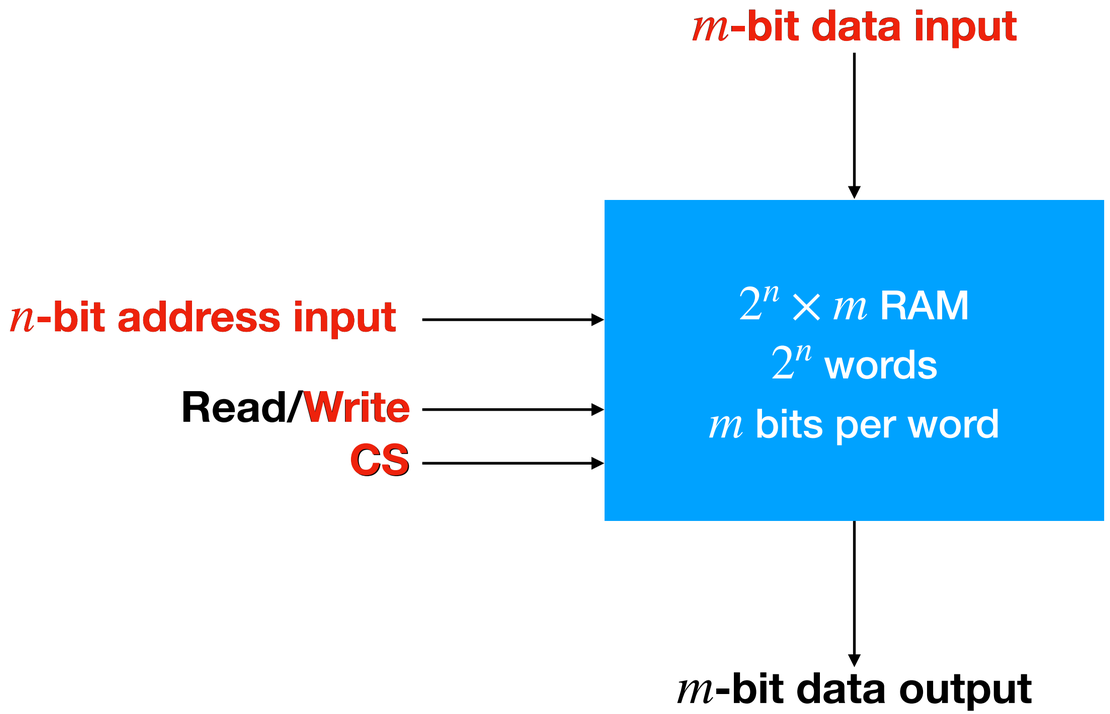
3. Activate the Write input



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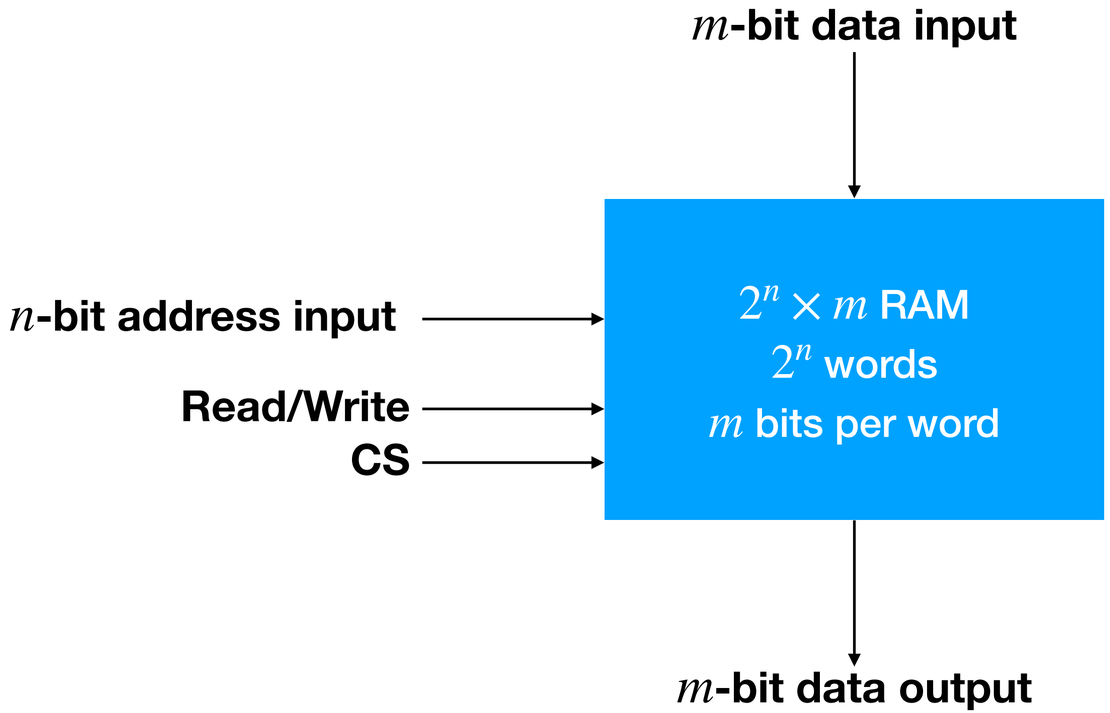

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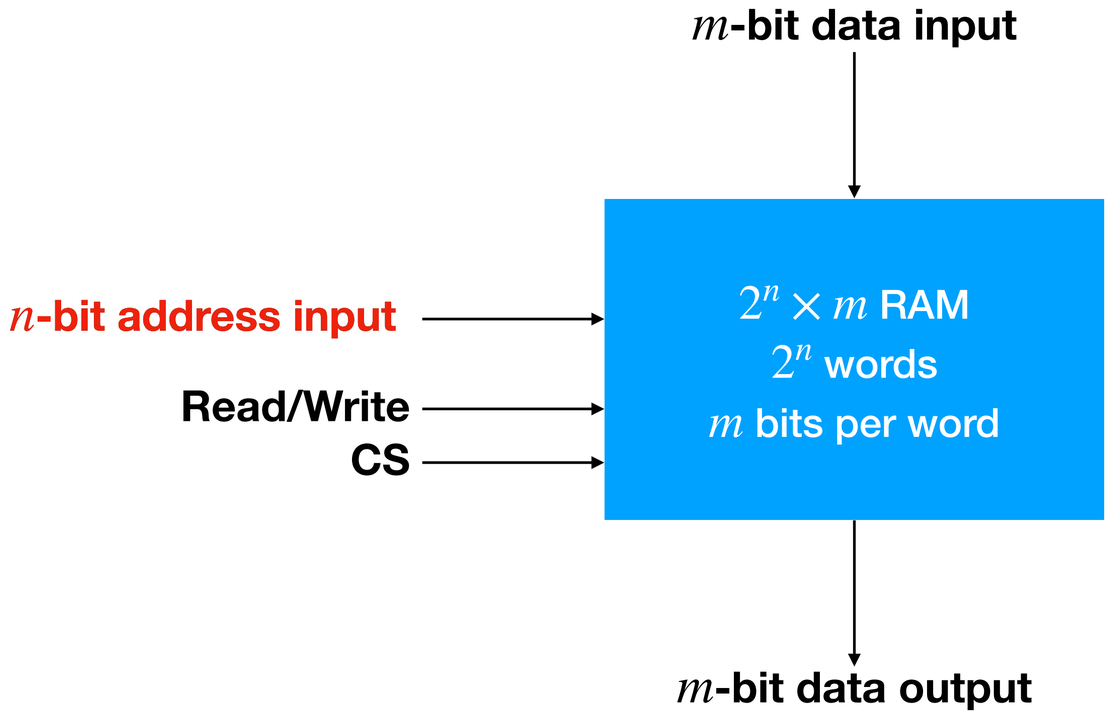

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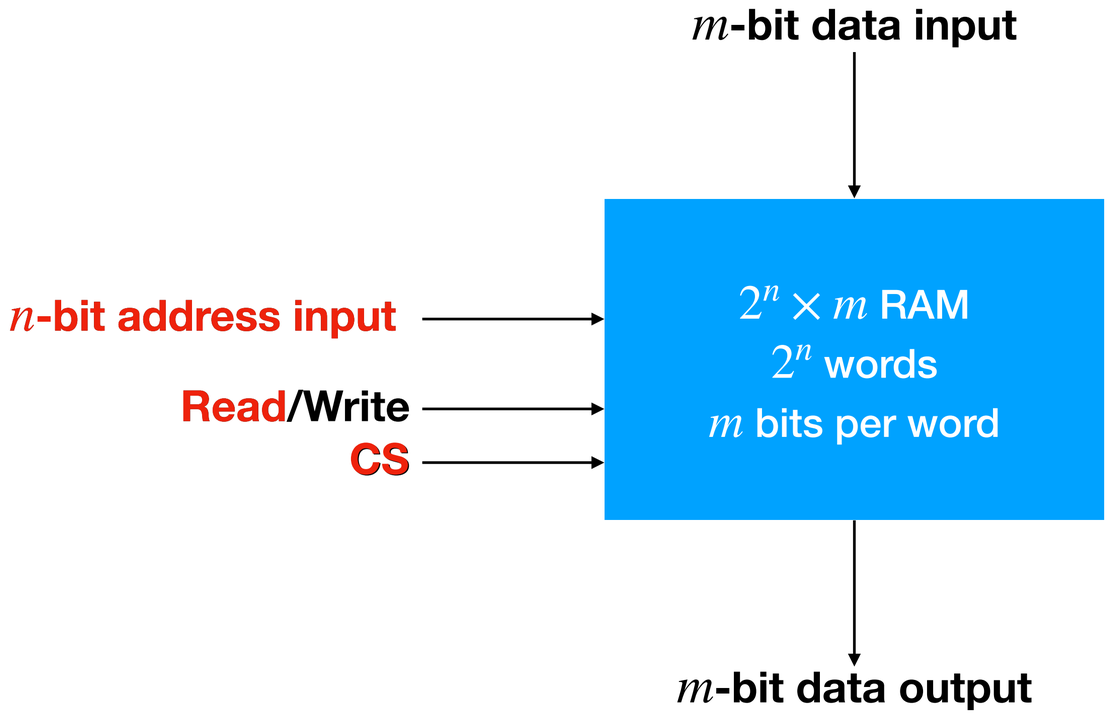
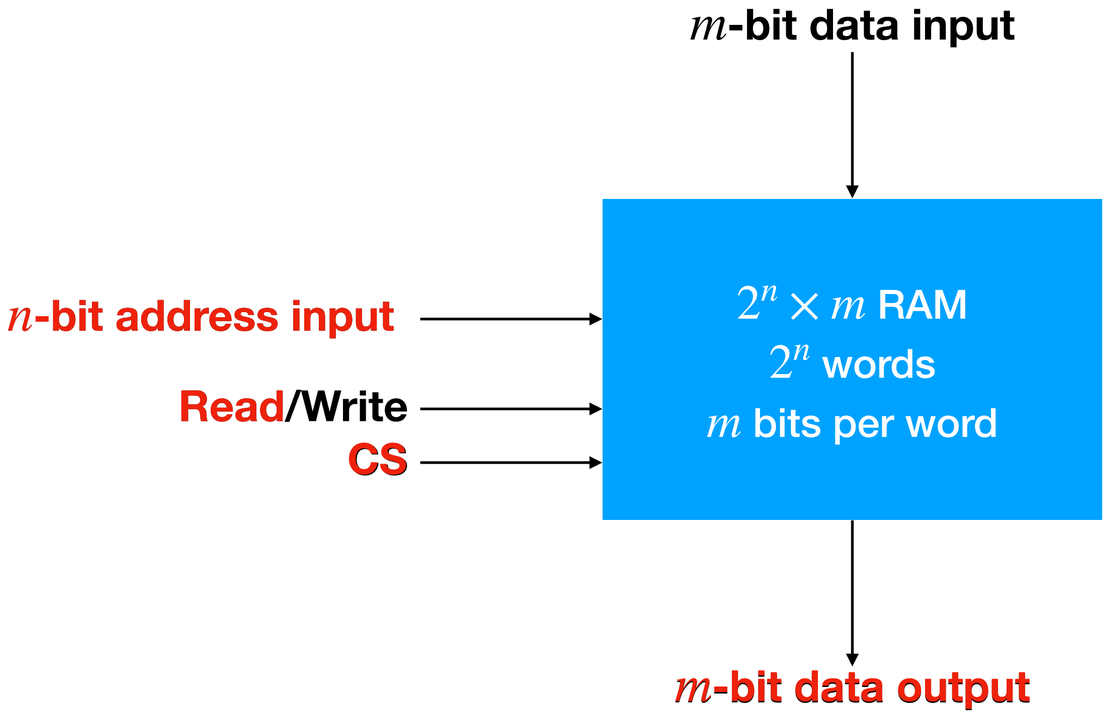
1. Apply the address of the desired word to the address lines
2. Activate the Read input



Demo

Steps for `Read`

1. Apply the address of the desired word to the address lines
2. Activate the Read input



Demo

P4
Summary

Summary Today

- Memory Definition: what are some memory devices? what are not memory devices?
- Read Only Memory
  - And its implementation using OR gate array and decoder
- Random Access Memory
  - What does the interface look like?

Review