

# Digital Circuits

ECS 371

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**Lecture 23**

**Office Hours:**

**BKD 3601-7**

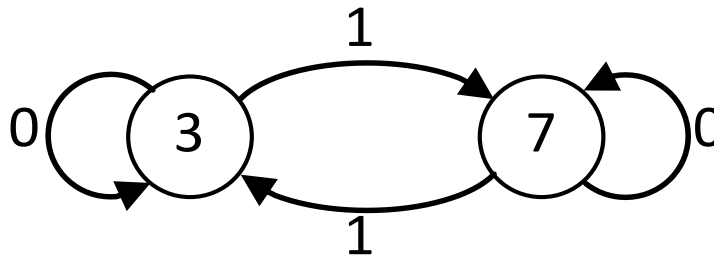
**Monday 9:00-10:30, 1:30-3:30**

**Tuesday 10:30-11:30**

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# Example (Your quiz from last time)

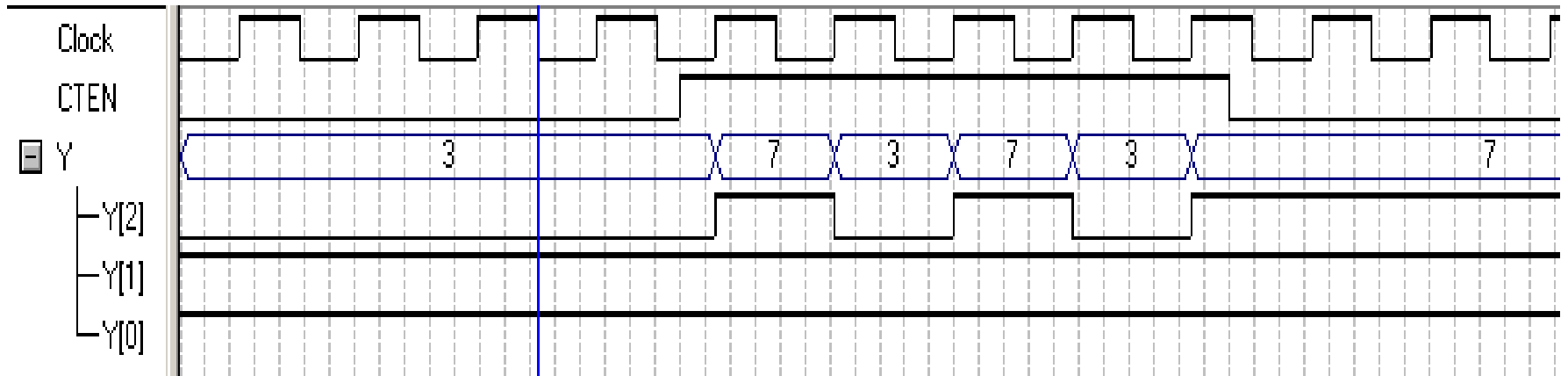
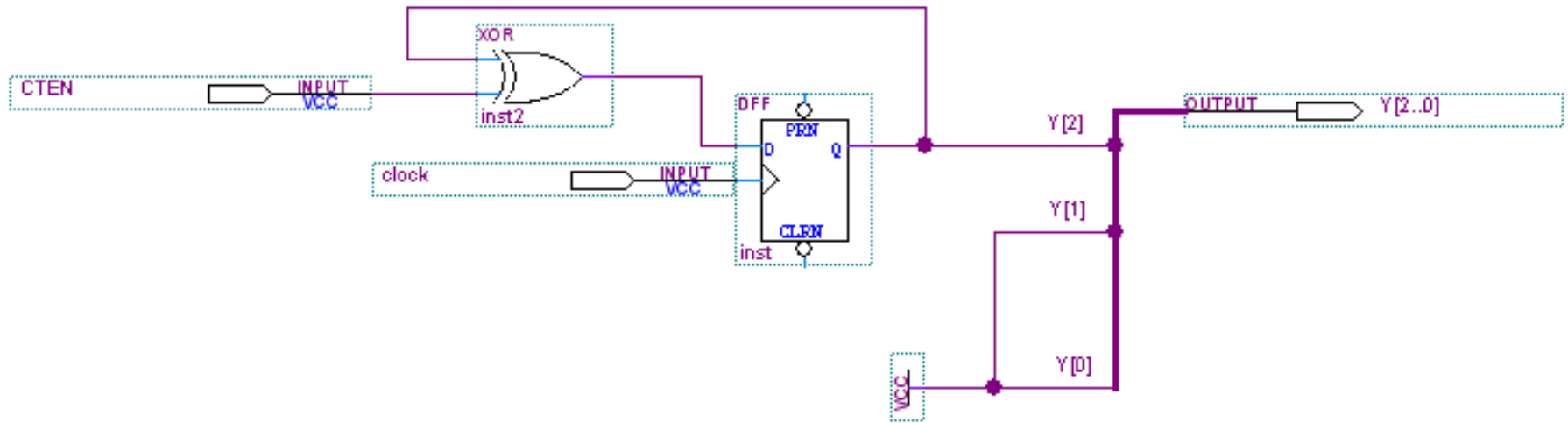
- Design a counter which satisfies all of the following requirements:
  1. Have one-bit input signal called CTEN.
  2. Have three-bit output signal called  $Y_2, Y_1, Y_0$ .
  3. The counting sequence agrees with the following state diagram:



The numbers on the arrows indicate the values of CTEN.

4. Use exactly one D flip-flop and one XOR gate.
5. No additional gate allowed.

# Solution

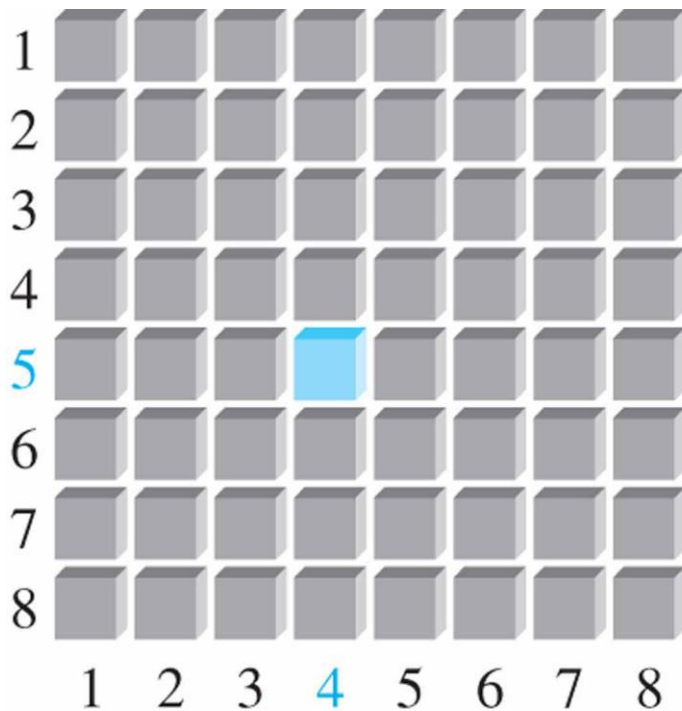


# Memory

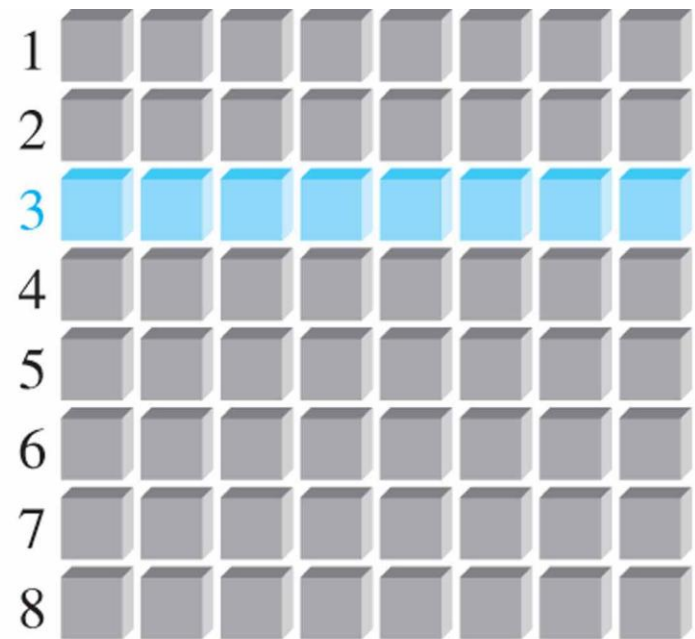
- Memory is the portion of a computer or other system that stores binary data.
- The smallest unit of binary data, as you know, is the **bit**.
- In many applications, data are handled in an 8-bit unit called a **byte**.
- Each storage element in a memory can retain either a 1 or a 0 and is called a **cell**.

# Memory Address

- The location of a unit of data in a memory is called the **address**.



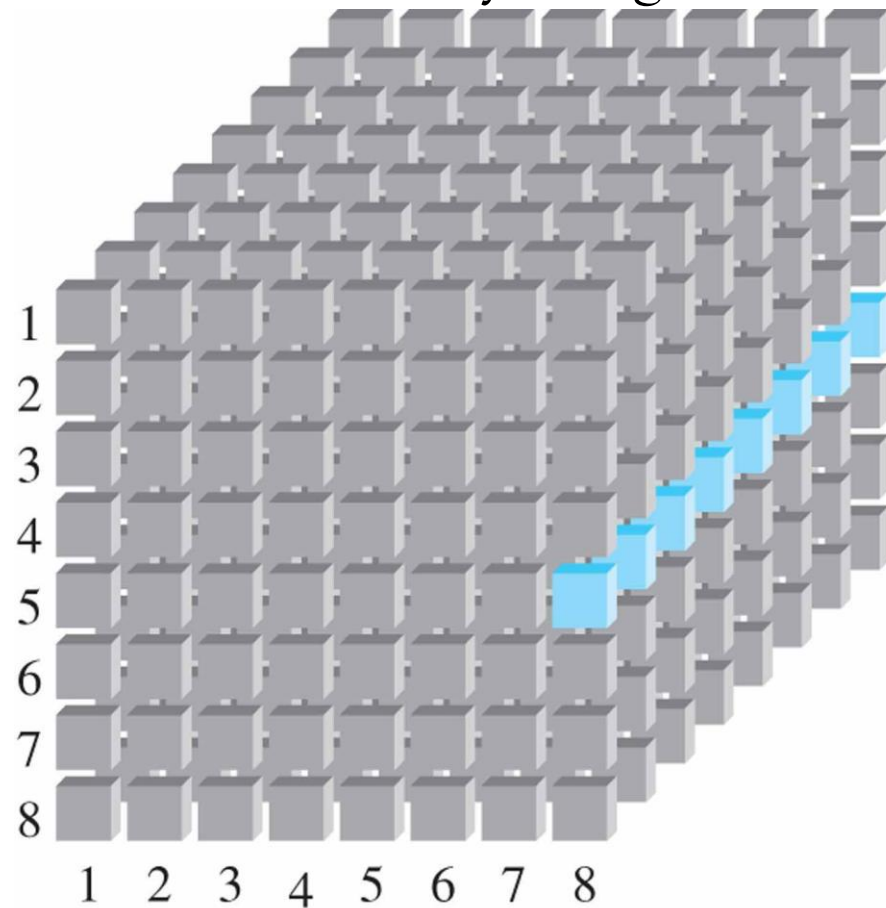
(a) The address of the blue bit is row 5, column 4.



(b) The address of the blue byte is row 3.

# Memory Address (2)

- The address depends on how the memory is organized into units of data.



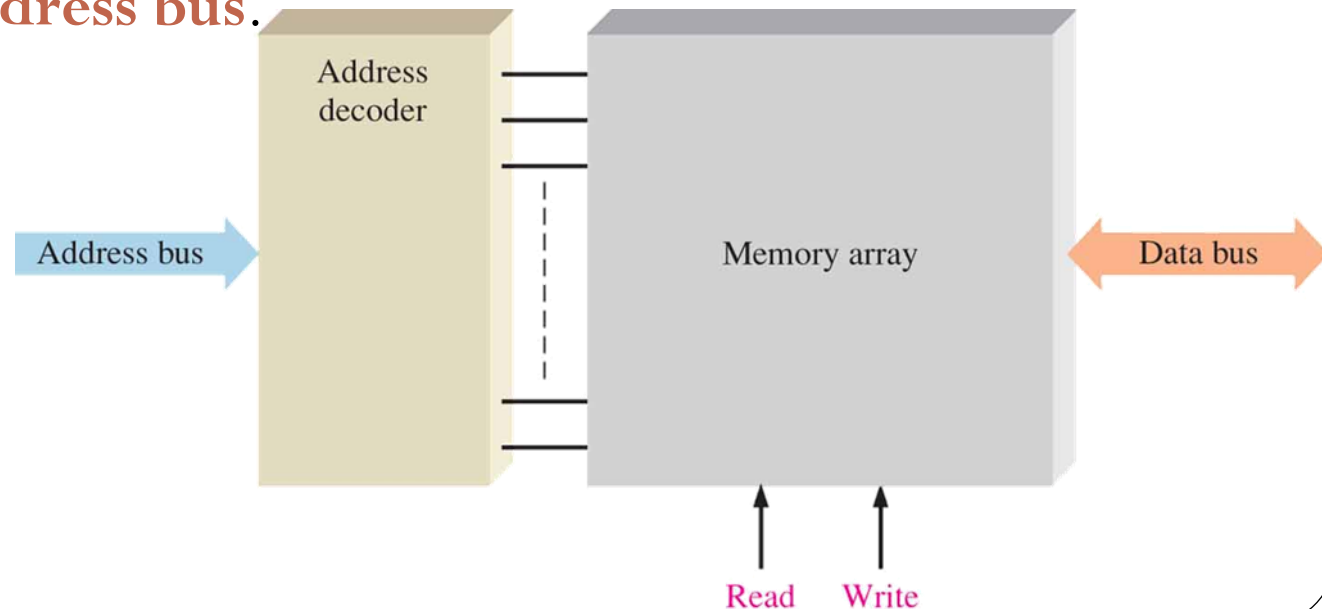
The address of the blue byte is row 5, column 8.

# Basic Memory Operations

- The **write operation** puts data into a specified address in the memory.
- The **read operation** copies data out of a specified address in the memory.
- The **addressing operation**, which is part of both the write and the read operations, selects the specified memory address.

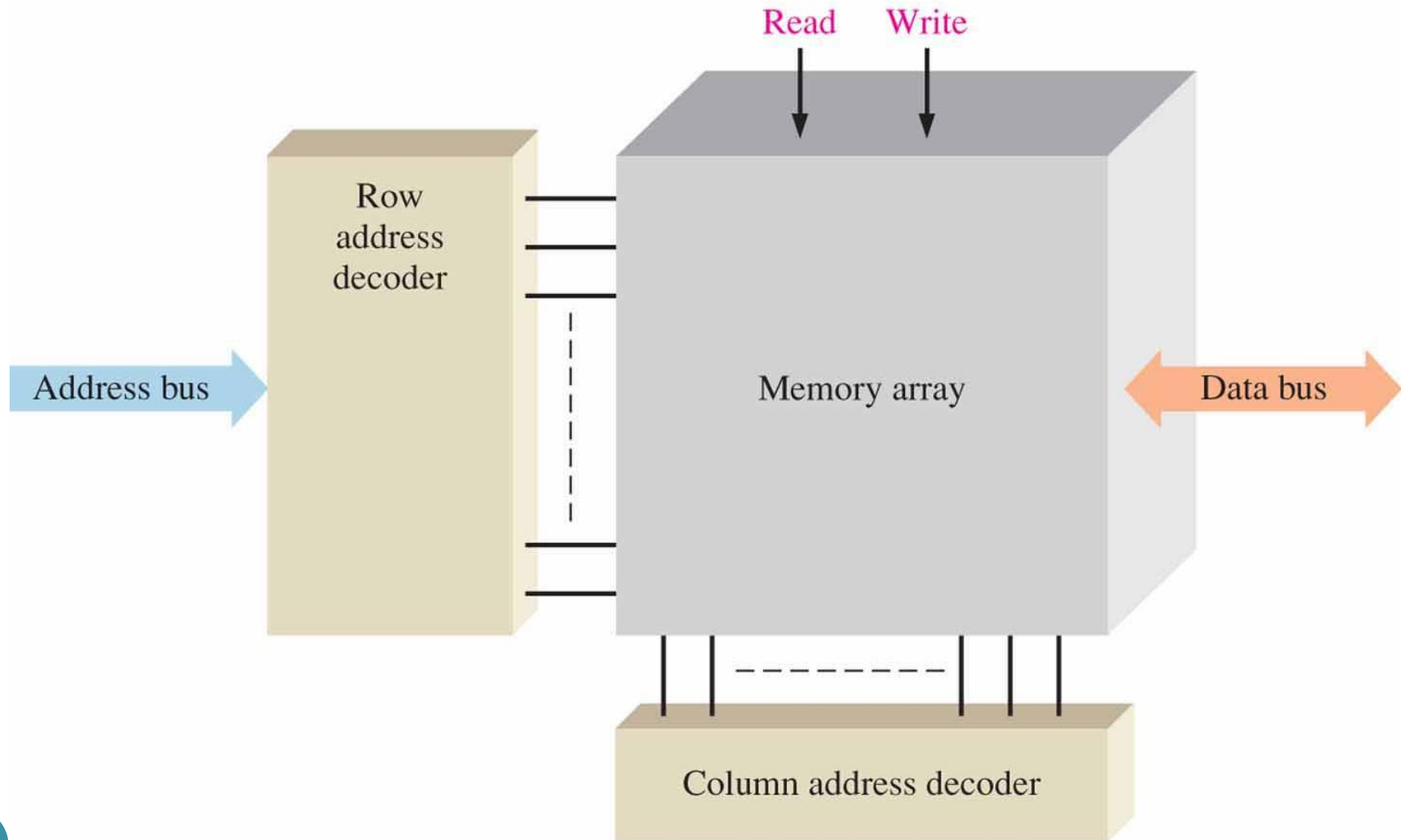
# Address Bus and Data Bus

- Data units go into the memory during a write operation and come out of the memory during a read operation on a set of lines called the **data bus**.
- The data bus is bidirectional, which means that data can go in either direction (into the memory or out of the memory).
- For a write or a read operation, an address is selected by placing a binary code representing the desired address on a set of lines called the **address bus**.

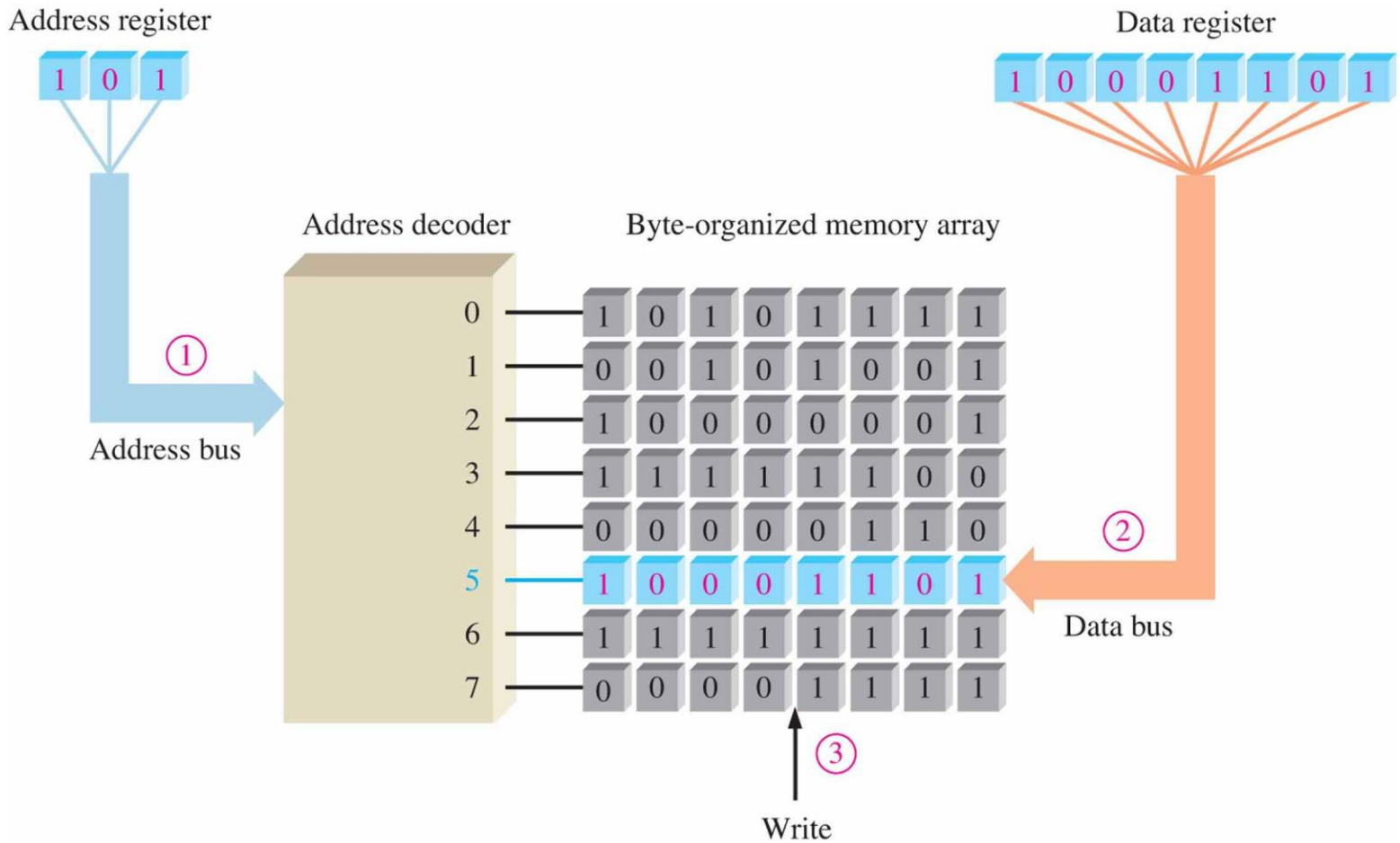




# 3D Memory Array

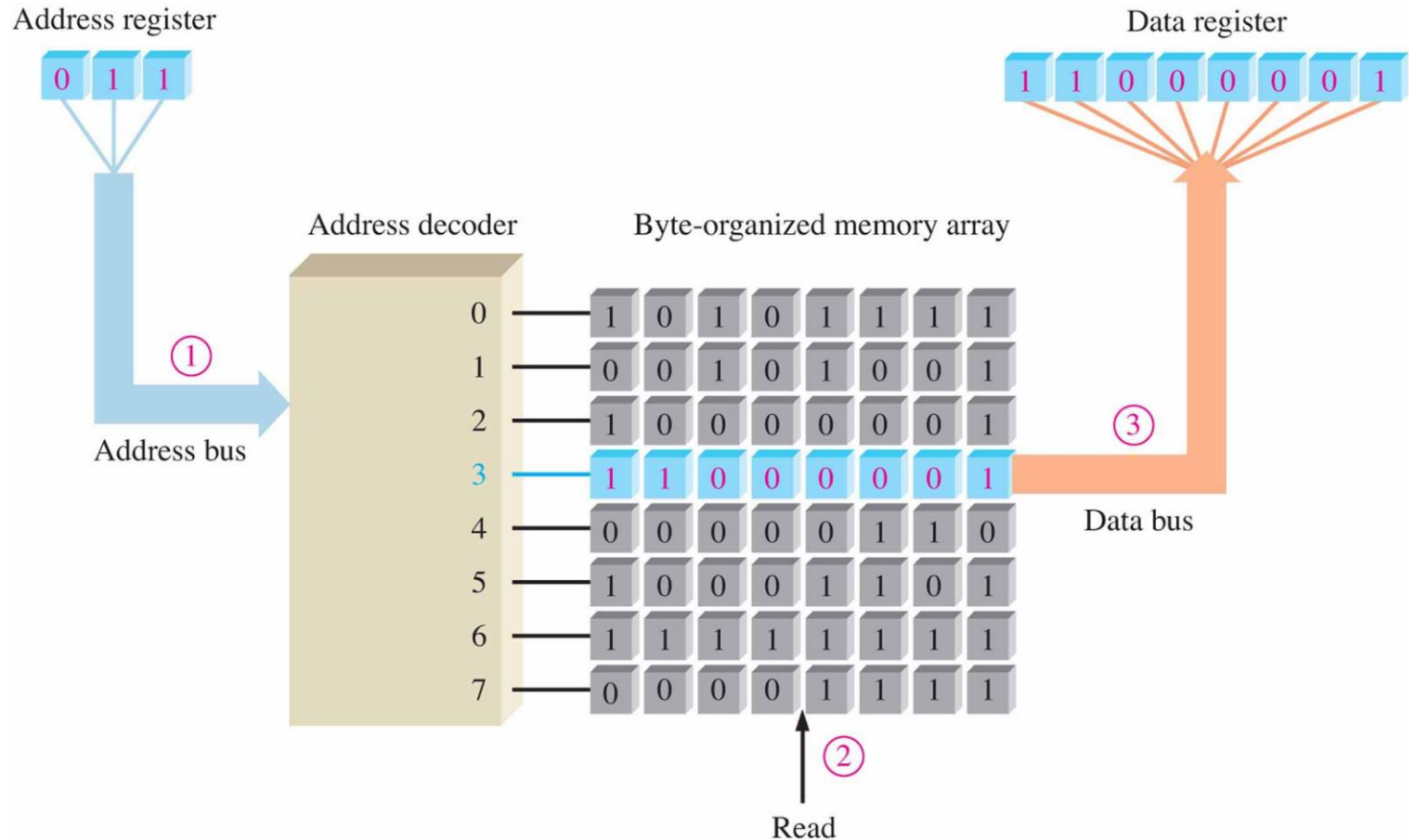


# Simplified Write Operation



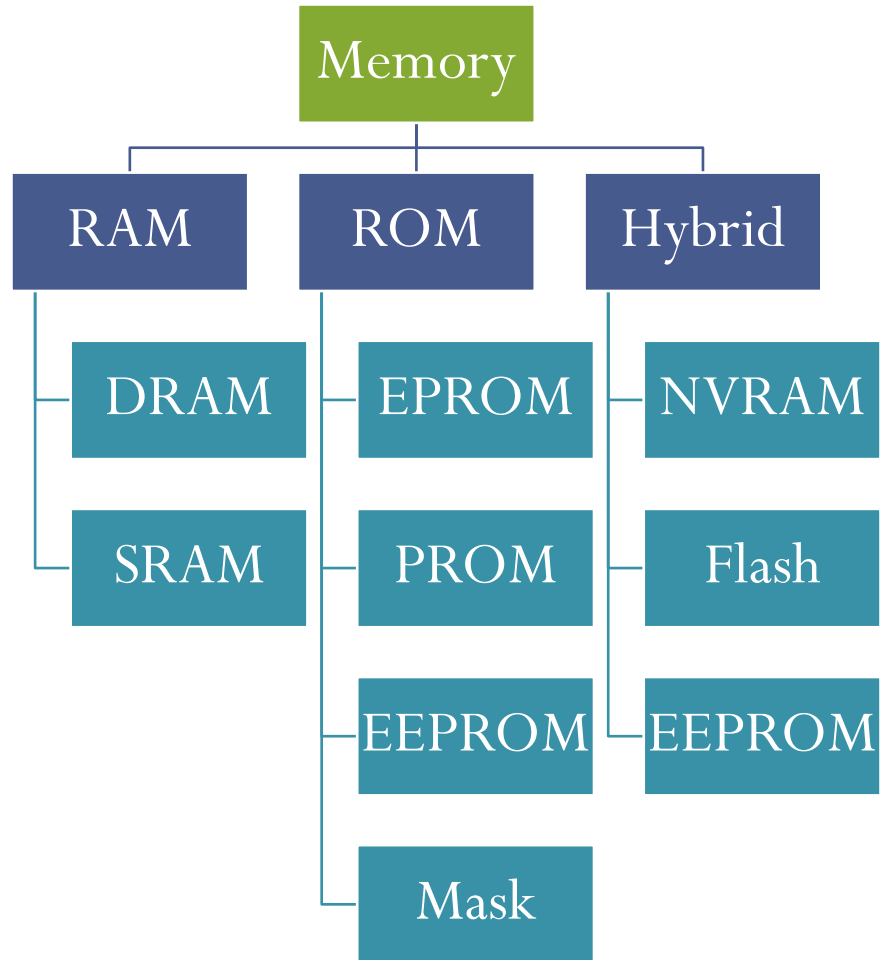
- ① Address code 101 is placed on the address bus and address 5 is selected.
- ② Data byte is placed on the data bus.
- ③ Write command causes the data byte to be stored in address 5, replacing previous data.

# Simplified Read Operation



- ① Address code 011 is placed on the address bus and address 3 is selected.
- ② Read command is applied.
- ③ The contents of address 3 is placed on the data bus and shifted into data register. The contents of address 3 is not erased by the read operation.

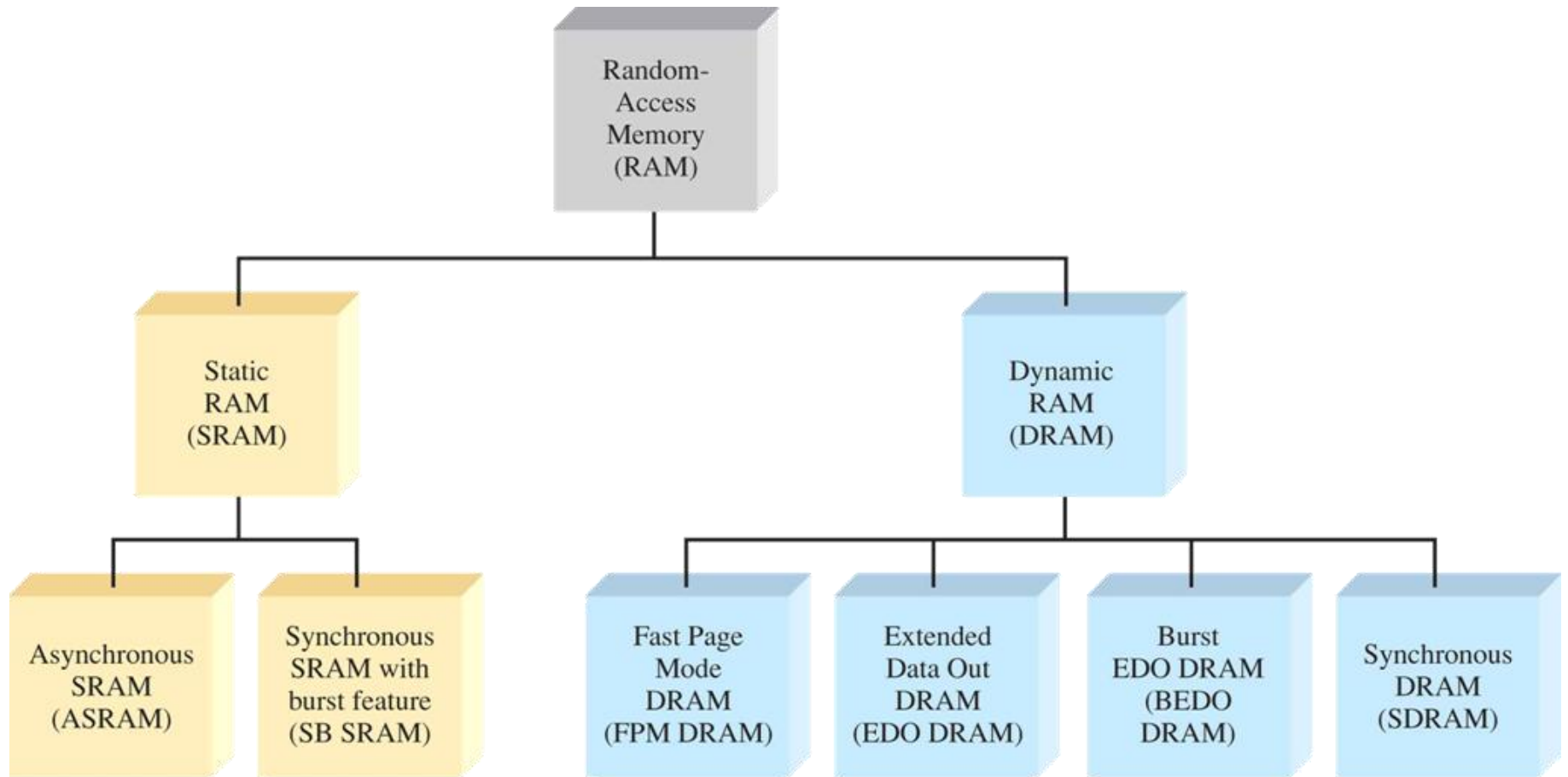
# Categories



# RAM: Random-Access Memory

- All addresses are accessible in an equal amount of time and can be selected **in any order** for a read or write operation.
  - This is in contrast to sequential memory devices such as magnetic tapes in which the mechanical movement of the storage medium forces the computer to access data in a fixed order.
- All RAMs have both read and write capability.
- **Volatile**: lose stored data when the power is turned off.
  - Typically used for short-term data storage
- Two major categories of RAM
  1. Static RAM (SRAM)
  2. Dynamic RAM (DRAM)

# RAM Family



# SRAM and DRAM

- Two major categories of RAM
  1. Static RAM (SRAM)
    - Generally use latches as storage elements
    - Can store data indefinitely as long as dc power is applied.
  2. Dynamic RAM (DRAM)
    - Use capacitors as storage elements
    - Can not retain data very long without the capacitors being recharged by a process called **refreshing**.
- Data can be read much faster from SRAMs
- DRAMs can store much more data for a given physical size and cost
  - because the DRAM cell is much simpler, and more cells can be crammed into a given chip area than in the SRAM.

# ROM: Read-only Memory

- **Nonvolatile:** Retain stored data even if power is turned off
  - Data are stored permanently or semi-permanently.
- Data can be read from a ROM, but there is no write operation as in the RAM.
- The ROM, like the RAM, is a random-access memory but the term RAM traditionally means a random-access read/write memory.