Tishk International University
Science Faculty
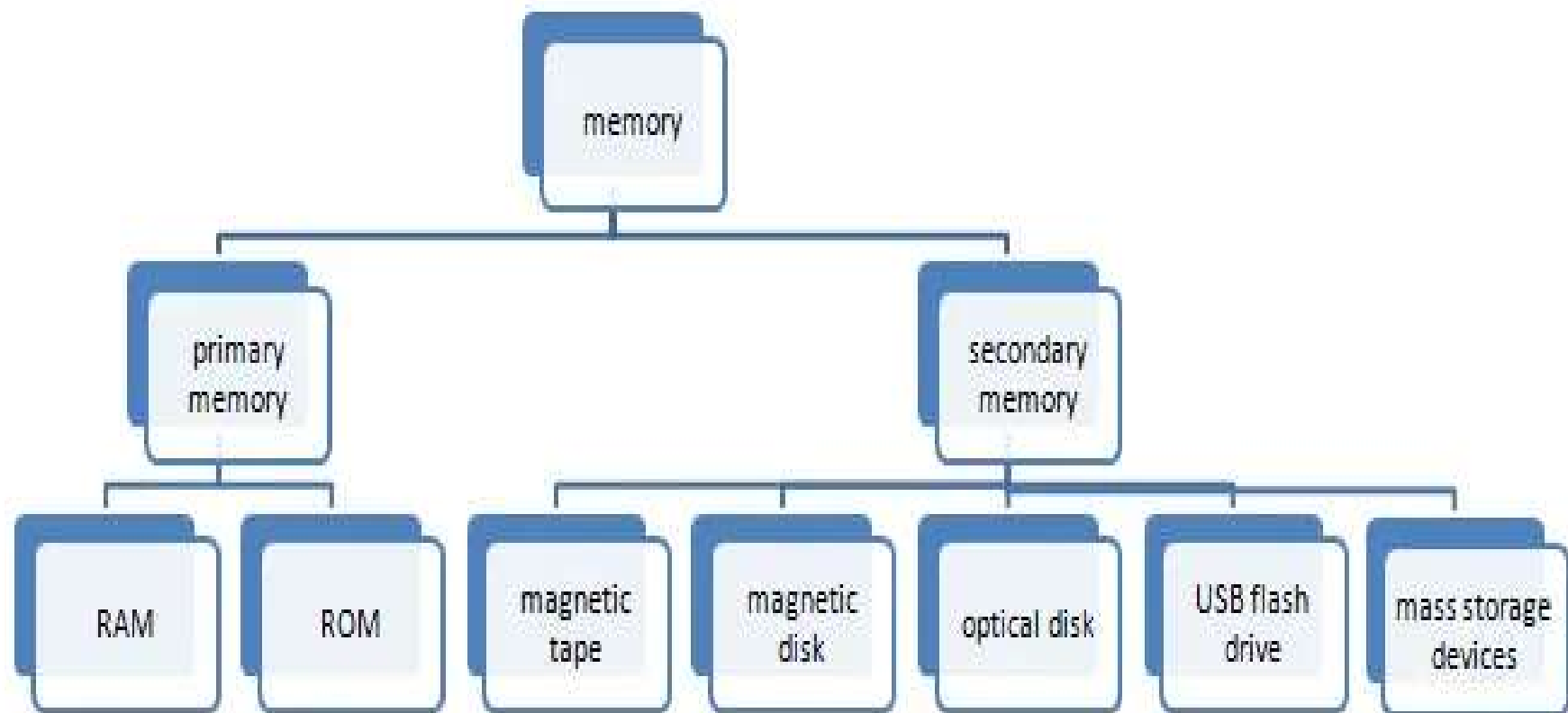**IT Department**

Computer Hardware

2nd Grade – Fall Semester

Instructor: Alaa Ghazi

Lecture 06: Memory Organization

Agenda

What is Main Memory?

Differences between Ram and ROM

Cache Memory

RAM Types

DRAM

SRAM

Memory Module Evolution

RAM Specifications

Generations of DDR RAM

Multi-Channel vs. Single Channel

Features of Multi-Channel RAM

Single Channel Memory

Multi-Channel Memory

Why to upgrade RAM?

How much RAM is needed?

What is Main Memory

- **Main Memory or (Random Access Memory - RAM):** is the area in a computer in which code and data is stored for quick access by the computer's processor.

- Program must be brought (from disk) into memory and placed within a process for it to be run

Differences Between RAM & ROM

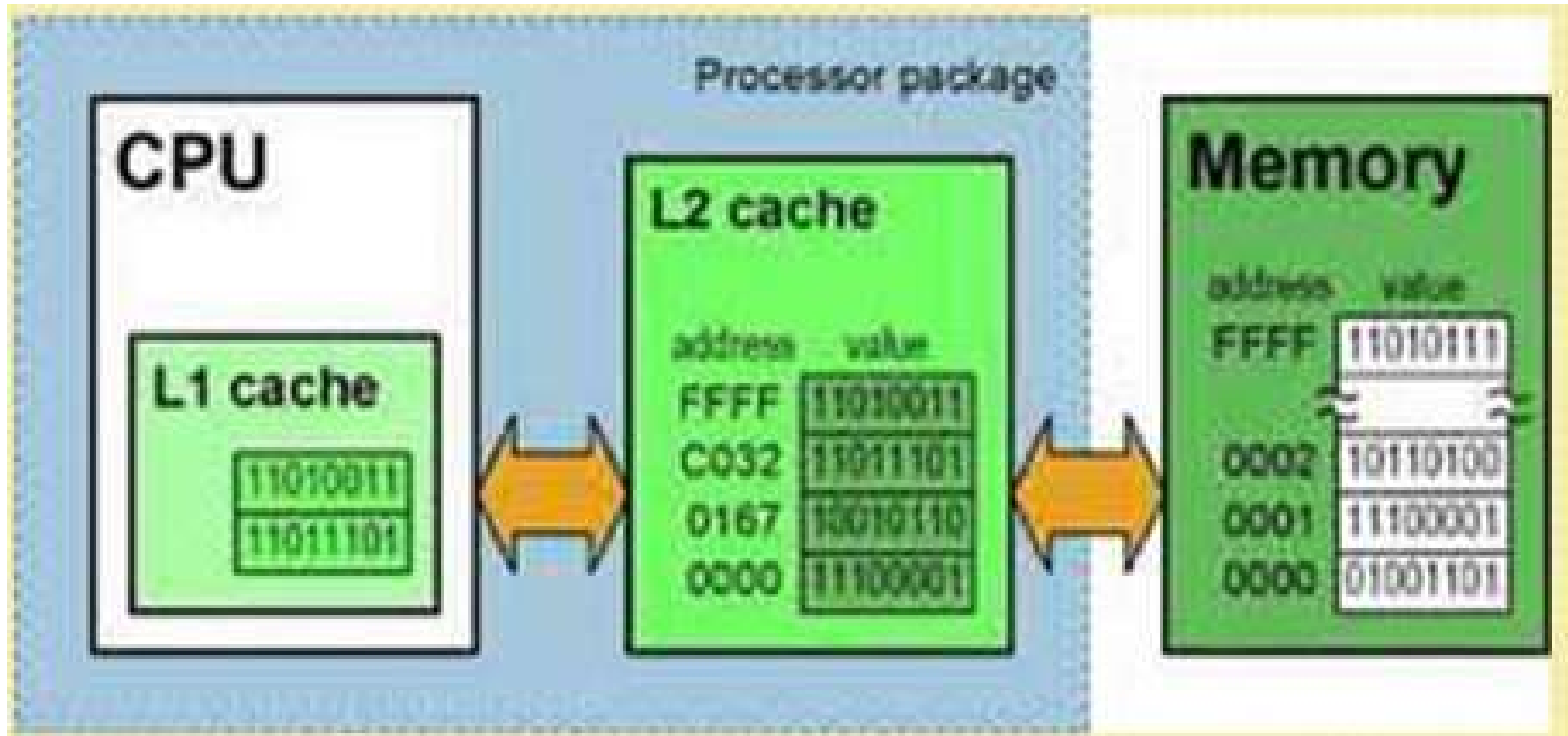|	RAM	ROM
Data and program	Stores during and after processing	Stored by manufacturer
Content	Stores information temporarily	Stores instructions (Information) permanently
Processing time	Very fast, but uses a lot of power	Fast, but uses very little power
Volatility	Volatile	Non-volatile

Cache Memory

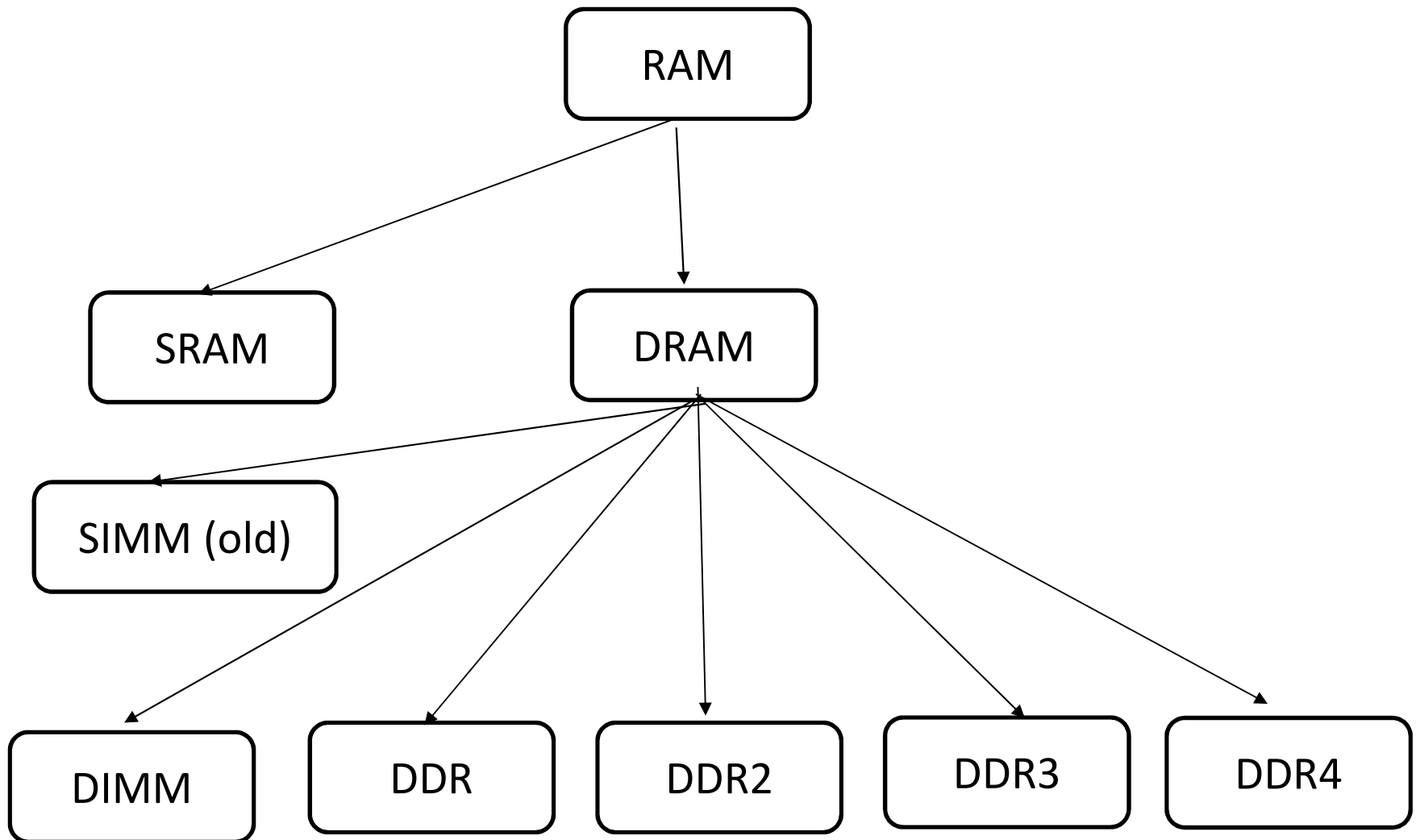- **Cache Memory**: is a small-sized type of volatile computer memory that provides high-speed access to a processor and stores frequently used code and data.

- It is the fastest memory in a computer, and is typically integrated onto the motherboard and directly embedded in the processor or main memory (RAM).

Secondary Memory   Primary Memory   Cache Memory   CPU - Processor
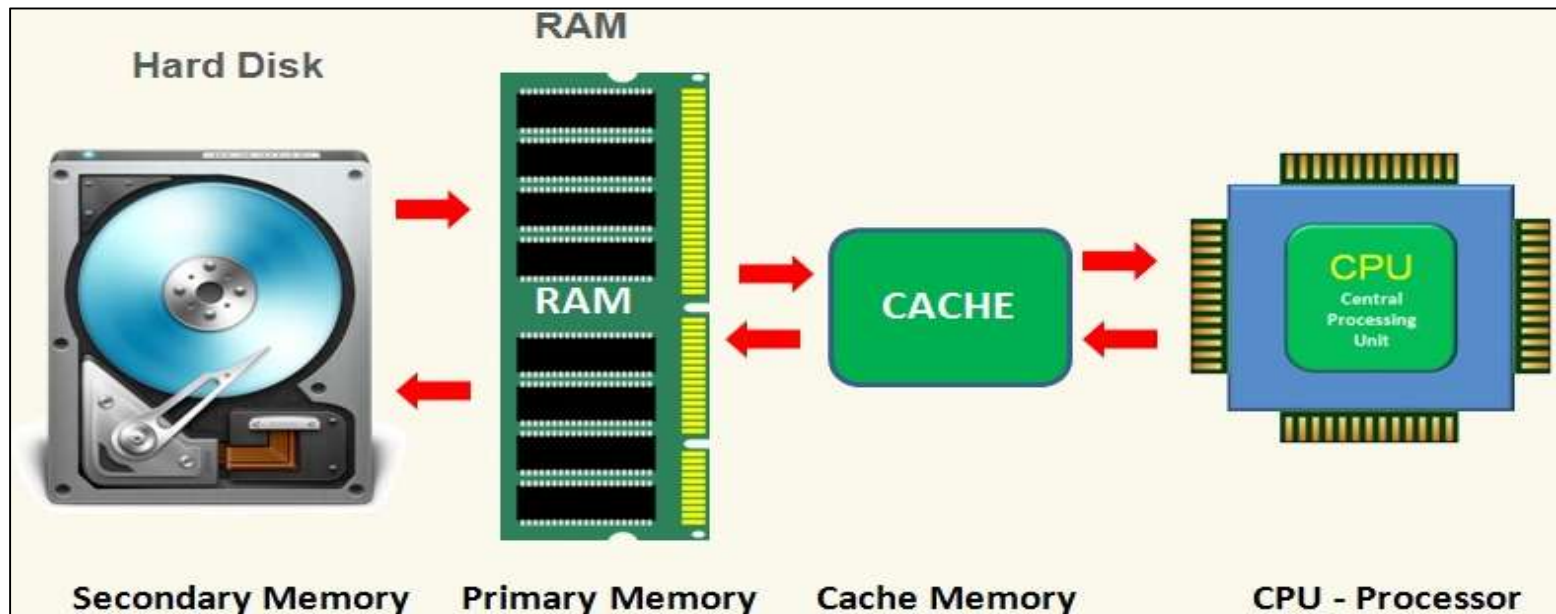
Cache Memory - Concept

RAM Types - Diagram

```
                          ┌─────────┐
                          │   RAM   │
                          └─────────┘
                          ╱         ╲
                  ┌─────────┐     ┌─────────┐
                  │  SRAM   │     │  DRAM   │
                  └─────────┘     └─────────┘
        ┌────────────┐
        │ SIMM (old) │
        └────────────┘
  ┌────────┐  ┌────────┐  ┌────────┐  ┌────────┐  ┌────────┐
  │  DIMM  │  │  DDR   │  │  DDR2  │  │  DDR3  │  │  DDR4  │
  └────────┘  └────────┘  └────────┘  └────────┘  └────────┘
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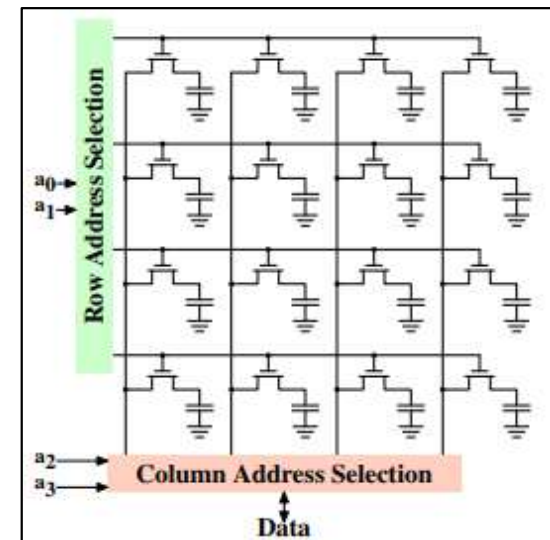
What is a DRAM?

Dynamic random access memory (DRAM), is a transistor and a capacitor are paired to create a memory cell, which represents a single bit of data. The capacitor holds the bit of information — a 0 or a 1
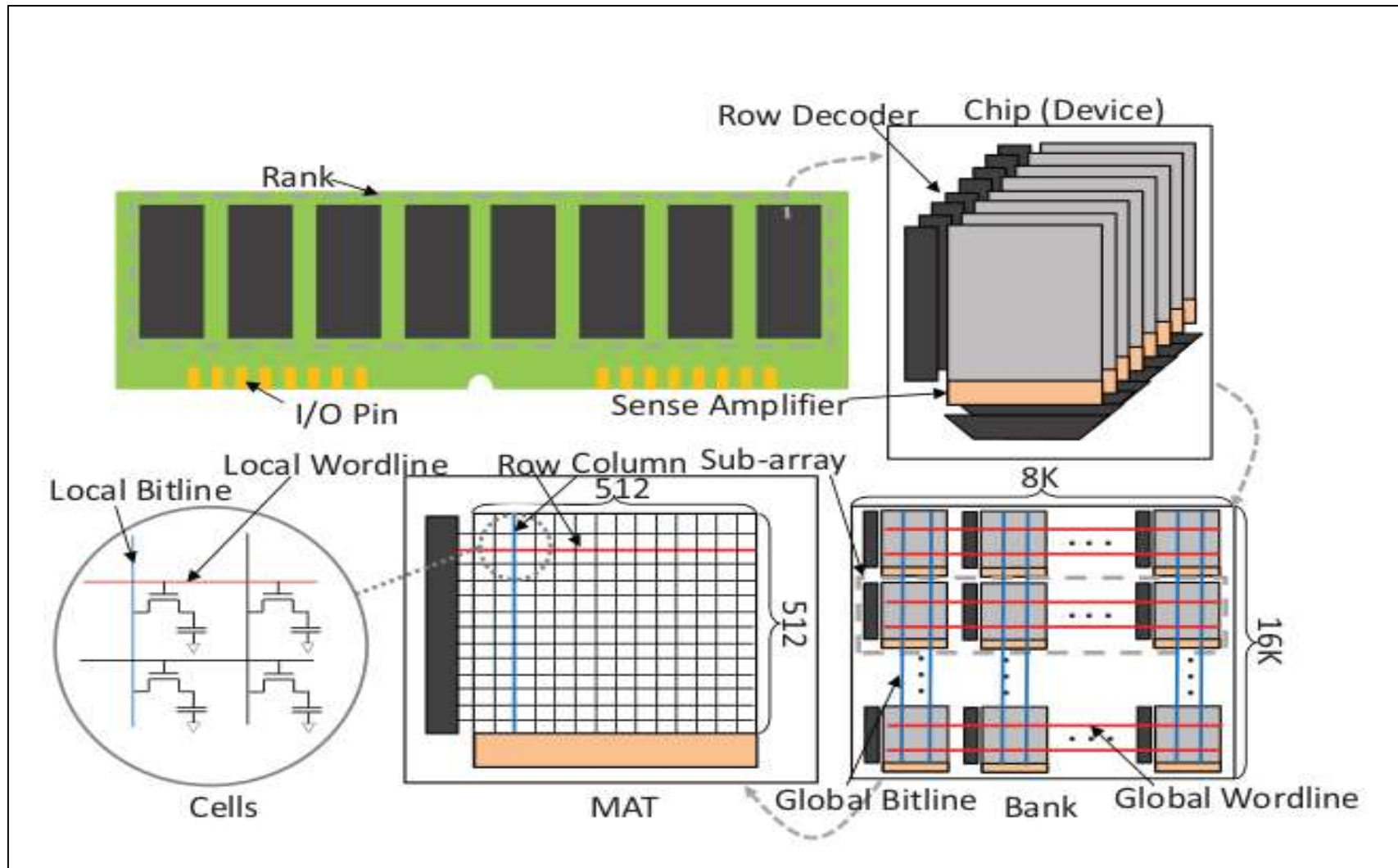
The capacitor in a dynamic RAM memory cell needs to be refreshed periodically or it will discharge to 0. This refresh operation is where dynamic RAM gets its name.

The CPU or the memory controller has to recharge all of the capacitors holding a 1 before they discharge.

# DRAM Structure
(not required in the exam)

What is a SRAM?

In Static RAM (SRAM), a form of flip-flop holds each bit of memory.

A flip-flop for a memory cell takes four or six transistors along with some wiring, but never has to be refreshed.

SRAM is significantly faster than DRAM.

However, because it has more parts, a static memory cell takes up a lot more space on a chip than a dynamic memory cell. Therefore, you get less memory per chip, and that increases its price.

Static RAM is fast and expensive, and dynamic RAM is less expensive and slower. So static RAM is used to create the CPU's speed-sensitive cache, while dynamic RAM forms the larger system RAM space.

Static RAM (SRAM) Cell
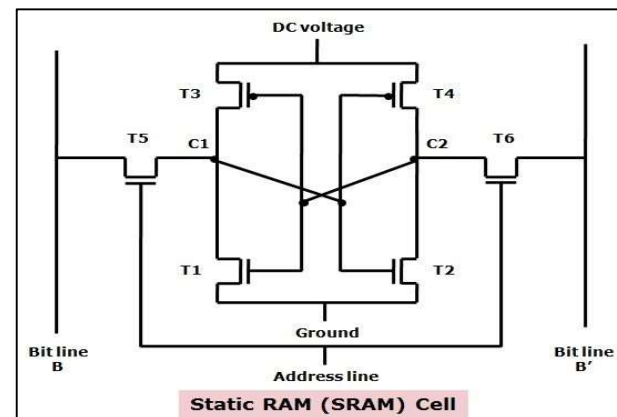
Memory Module Evolution

Memory chips are normally only available as part of a card called a **memory module**.

The kinds of board and connector used for RAM in desktop computers have evolved over the past few years.

The first types were proprietary, meaning that different computer manufacturers developed memory boards that would only work with their specific systems.

The next generation was called **Single in-line Memory Module** (**SIMM**) which is a memory board that used a 30-pin connector and was about 3.5 x 0.75 inches in size.

In most computers, you had to install SIMMs in pairs of equal capacity and speed. This is because the width of the bus is more than a single SIMM.

The next generation was **Dual in-line Memory Module (DIMM).** DIMMs can be installed singly instead of in pairs.

Some brands of laptop computers use RAM based on the **Small Outline Dual in-line Memory Module (SODIMM)** configuration. SODIMM cards are small, about 2 x 1 inch and have 144 or 200 pins.

Memory Modules Samples

Note, as well as the different number of pins, the different spacing of the slots in the connector-edge

MicroDIMM (rare)

72 pin SODIMM (rare)

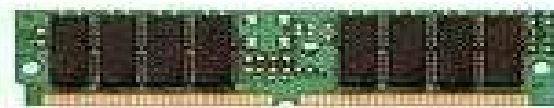144 pin SDRAM SODIMM
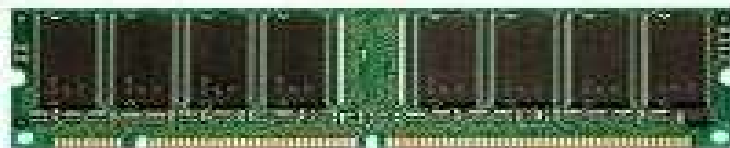
200 pin DDR SODIMM

200 pin DDR-2 SODIMM

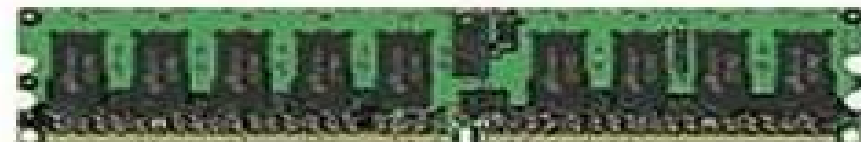100 pin DIMM printer RAM

30 pin SIMM

72 pin SIMM

168 pin SDRAM DIMM

184 pin RAMBus RDRAM RIMM

184 pin DDR DIMM

240 pin DDR-2 DIMM

RAM Specifications

1. **Memory Size** in GB: should not exceed CPU and motherboard maximum memory size

2. **DDR Generation:** supported by motherboard (see next slides)

3. **Frequency or clock speed:** is the maximum number of commands it can handle per second, measured in the unit of Megahertz (MHz).

4. **Column Address Strobe (CAS) Latency or CL** is the amount of time between sending a READ command to and the time when the data is available. It is measured in nano-seconds (ns).

5. **Memory Bandwidth**: The rate at which a RAM can read or write data to/from the processor and vice versa.

6. **Memory Channels :** see next slides

7. **ECC Support**: Error Correction Code (ECC) Memory has an additional register between the Memory Controller and the DRAM, so it has the ability to auto-detect and correct memory errors, thus preventing data corruption.

Generations of DDR RAM

1. Transfer rate is doubling from one generation to another
2. Voltage drops in every new generation
3. The generations are not compatible mechanically and electrically.

DDR SDRAM Standard	Internal rate (MHz)	Bus clock (MHz)	Prefetch	Data rate (MT/s)	Transfer rate (GB/s)	Voltage (V)
DDR	133-200	133-200	2n	266-400	2.1-3.2	2.5/2.6
DDR2	133-200	266-400	4n	533-800	4.2-6.4	1.8
DDR3	133-200	533-800	8n	1066-1600	8.5-14.9	1.35/1.5
DDR4	133-200	1066-1600	8n	2133-3200	17-21.3	1.2

Generations of DDR RAM
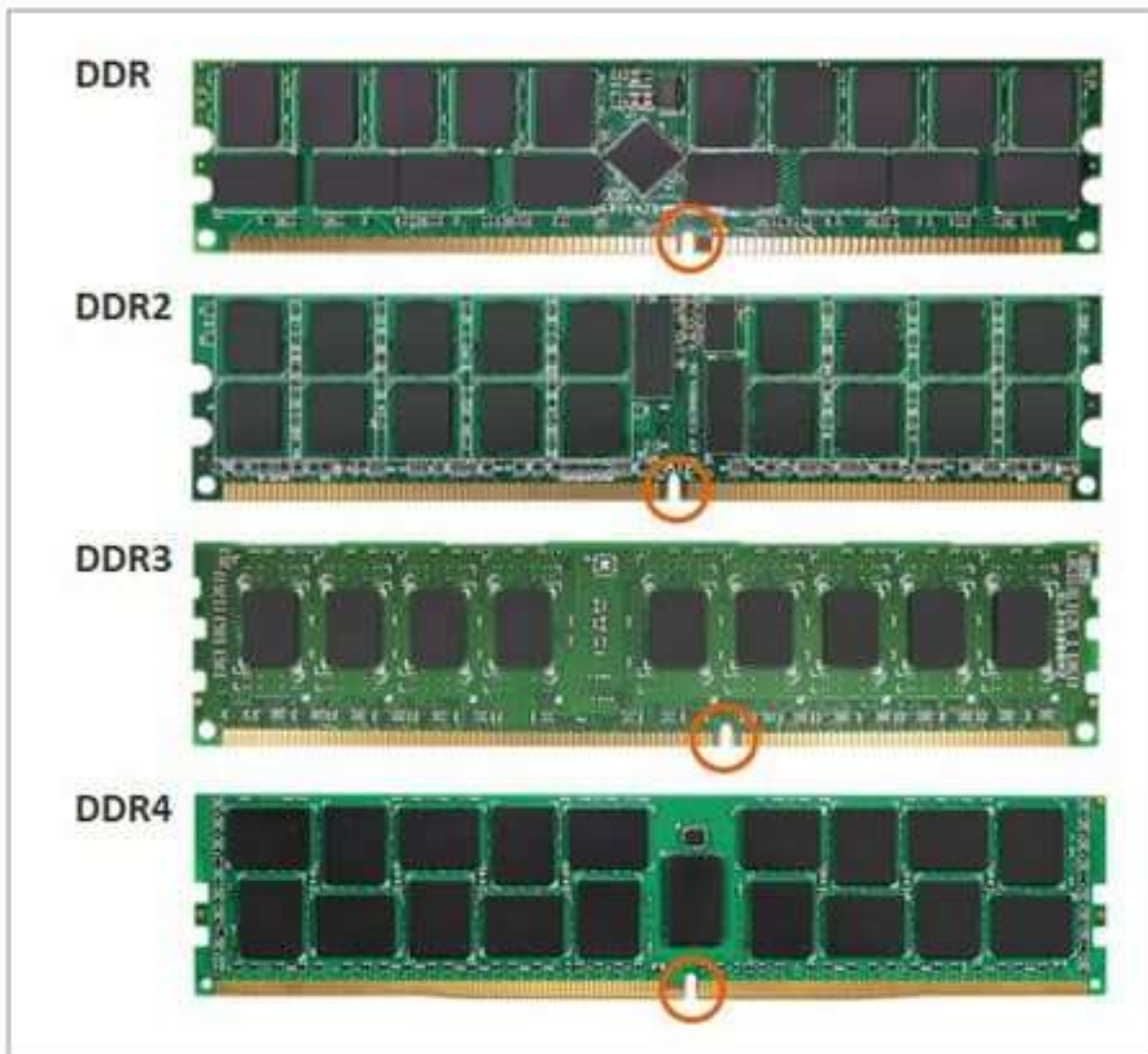
DDR4 vs DDR5

Features	DDR4	DDR5	DDR5 Advantages
IO Voltage	1.2 V | CA SSTL	1.1 V | CA PODL	Lower power
Power Management	On motherboard	On DIMM PMIC	Better power efficiency Better scalability
Channel Architecture	72-bit data channel (64 data + 8 ECC) 1 channel per DIMM	40-bit data channel (32 data + 8 ECC) 2 channels per DIMM	Higher memory efficiency Lower latency
Burst Length	BC4, BL8	BC8, BL16	Higher memory efficiency
Max. Die Density	16Gb SDP → 64GB DIMMs	64Gb SDP → 256GB DIMMs	Higher capacity DIMMs

Features of Multi-Channel RAM

1. **Automatic Detection**: When you install two memory modules, it'll run on a dual memory channel. When you install four memory modules, your system will run on a quad memory channel.

2. **Better Memory Bandwidth**: Benchmarks have proven that lower capacity memory modules offers better memory bandwidth allows the entire system to perform better.

3. **Redundancy:** if one RAM module fails to operate, you can rely on the other one. However, this is not possible with a single channel memory

4. **Economical:** Multiple channel memory is more economical than single-channel with the same total size.
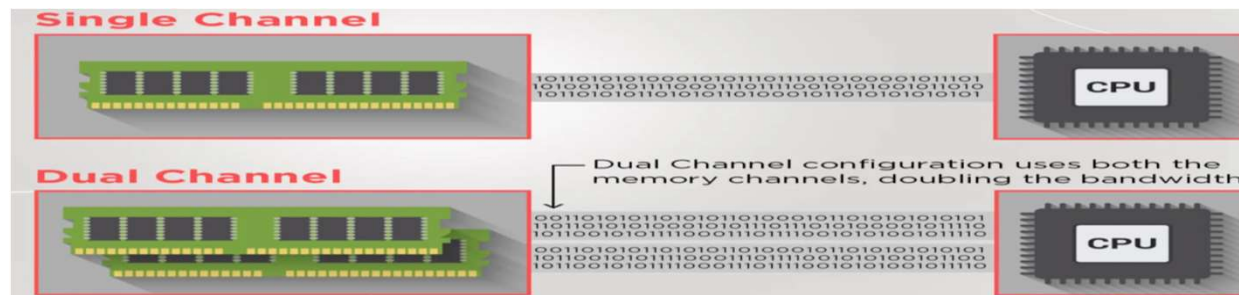
Single Channel Memory

- A **Single Channel** memory is a RAM configuration where you can insert one RAM stick. It's one of the most common memory channels available out there.

- **Pros:**
  - Can fit in any motherboard
  - No issues in compatibility

- **Cons:**
  - it is expensive compared to multi-channel with same capacity.
  - Less memory bandwidth compared to Multi-channel

Multi-Channel Channel Memory

- **Multi-Channel** If the motherboard supports a dual or quad memory channels, then it is possible to install two or four individual memory sticks and double the bandwidth accordingly.

- **Pros:**
  - Double memory bandwidth of Single channel
  - More economical than single channel

- **Cons:**
  - It can not fit in any motherboard
  - It's generally not advised to mix RAM units of different brands, storage sizes, and speeds.

Why to upgrade RAM?

- Upgrading old computers

- Ability to handle more complex projects

- Improve performance