

3.5 MEMORY HIERARCHY

1. Introduction

A computer system uses different types of memory to store data, instructions and results. These memories differ in terms of speed, storage capacity, cost and access time. No single memory can be very fast, very large and very cheap simultaneously. Therefore, different memories are arranged in a hierarchical order, known as Memory Hierarchy, to achieve a balance between high performance and large storage capacity.

Definition:

Memory hierarchy is an arrangement of different types of computer memories in a systematic order according to their speed, capacity, cost and access time.

(कंप्यूटर में उपलब्ध विभिन्न प्रकार की मेमोरी को उनकी गति, क्षमता, लागत और एक्सेस समय के आधार पर क्रमबद्ध रूप से व्यवस्थित करने की प्रक्रिया को मेमोरी पदानुक्रम कहते हैं।)

2. Need of Memory Hierarchy

- An ideal memory should be very fast, very large and very cheap, but such a memory is not practically possible.
- High-speed memories (like registers, cache) are expensive and have low capacity.
- Large-capacity memories (like HDD, tape) are cheaper but slower.
- Memory hierarchy provides a combination of these memories so that we can get the advantage of both fast access and large storage.
- It also reduces the waiting time of CPU and improves overall system performance.

3. Levels of Memory Hierarchy

The memory hierarchy consists of the following levels (from fastest to slowest):

- 1 CPU Registers
- 2 Cache Memory (L1, L2, L3)
- 3 Primary Memory (RAM, ROM)
- 4 Secondary Memory (HDD, SSD, etc.)
- 5 Backup/Archival Storage (Magnetic Tape, Optical Storage)

4. Memory Hierarchy Diagram

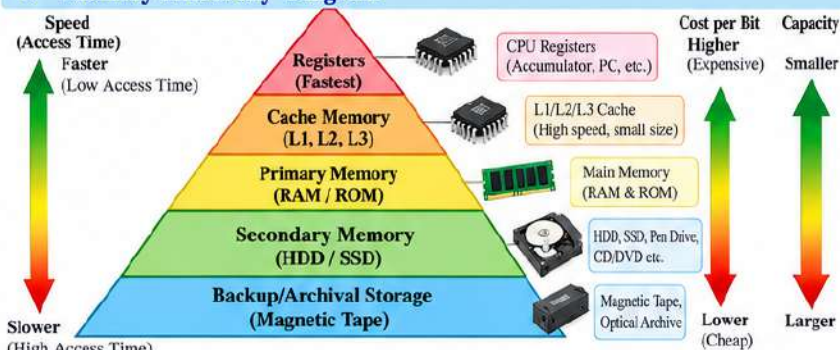


Fig. 3.1 Memory Hierarchy Pyramid

(10 Marks)

5. Description of Each Level

5.1 CPU Registers (Top Level)

- Located inside the CPU.
- Fastest memory with minimum access time (≈ 0.1 ns).
- Very small storage capacity (few bytes).
- Highest cost per bit.
- Used to store immediate data, addresses and instructions.
- **Examples:** Accumulator, Program Counter (PC), Instruction Register (IR), Memory Address Register (MAR), Memory Data Register (MDR).



Fig. 3.2 CPU Registers

5.2 Cache Memory (L1, L2, L3)

- Located between CPU and main memory.
- Very fast memory, built using SRAM.
- Stores frequently used data and instructions.
- Smaller capacity than RAM but faster.
- **Types:** L1 Cache (fastest, smallest), L2 Cache (larger), L3 Cache (largest).



Fig. 3.3 Cache Memory

5.3 Primary Memory (Main Memory)

- Directly accessible by CPU.
- Consists of RAM (volatile) and ROM (non-volatile).
- Stores currently running programs and data.
- Moderate speed and medium capacity.



Fig. 3.4 RAM Module

5.4 Secondary Memory

- Non-volatile storage used for long-term storage.
- Large storage capacity.
- Slower than primary memory.
- **Examples:** Hard Disk Drive (HDD), Solid State Drive (SSD), CD/DVD, Pen Drive, Memory Card etc.



Fig. 3.5 Hard Disk Drive (HDD)

5.5 Backup / Archival Storage (Lowest Level)

- Used for backup and archival purpose.
- Very large capacity and very low cost.
- Slowest access time.
- **Examples:** Magnetic Tape, Optical Archive.



Fig. 3.6 Magnetic Tape

6. Comparison of Memory Levels

Level of Memory	Example	Speed (Access Time)	Capacity	Cost per Bit	Volatility
Registers	CPU Registers	Very High (≈ 0.1 ns)	Very Small (Bytes)	Very High	Volatile
Cache Memory	L1, L2, L3	High ($\approx 1-10$ ns)	Small (KB-MB)	High	Volatile
Primary Memory	RAM, ROM	High ($\approx 10-100$ ns)	Medium (MB-GB)	Medium	RAM: Volatile ROM: Non-volatile
Secondary Memory	HDD, SSD, CD/DVD, Pen Drive	Low ($\approx$ ms)	Large (GB-TB)	Low	Non-volatile
Backup Storage	Magnetic Tape	Very Low ($\approx$ seconds)	Very Large (TB-PB)	Very Low	Non-volatile

7. Important Points / Characteristics

- As we move from top to bottom in the hierarchy:
 - Speed decreases.
 - Access time increases.
 - Storage capacity increases.
 - Cost per bit decreases.
 - Frequency of access decreases.
 - Top level memories are fast and costly.
 - Bottom level memories are slow and cheap.
 - This hierarchy achieves a balance between speed and storage capacity.

3.6 PRIMARY AND SECONDARY MEMORY (10 Marks)

1. Introduction (परिचय)

Computer में data, instructions, programs और results को store करने के लिए memory का उपयोग किया जाता है। Computer memory को broadly दो भागों में विभाजित किया जाता है - Primary Memory (Main Memory) और Secondary Memory (Auxiliary Memory).

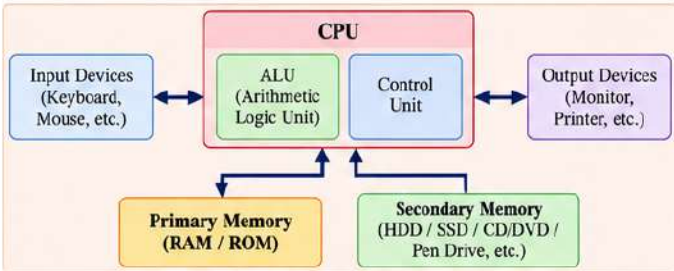


Fig. 3.1 Position of Primary and Secondary Memory in Computer System

3. Primary Memory (मुख्य मेमोरी)

Primary memory वह मेमोरी है जिसे CPU directly access कर सकता है। यह processing के समय उपयोग होने वाले data, instructions और programs को store करती है। यह fast होती है लेकिन इसकी storage capacity सीमित होती है। यह दो प्रकार की होती है - RAM और ROM.

3.1 RAM (Random Access Memory)

- Volatile memory (power off पर data नष्ट हो जाता है)
- Read और Write दोनों संभव हैं।
- Currently running programs और data store होते हैं।
- High speed और low access time.



Fig. 3.3 RAM Module

3.1.1 Types of RAM

A. SRAM (Static RAM)

- Flip-flop circuit में data store होता है।
- Very fast, expensive.
- Refresh की आवश्यकता नहीं।
- Low capacity.
- Cache memory में उपयोग होता है।

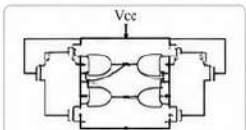


Fig. 3.4 SRAM Cell (Using Flip-Flop)

B. DRAM (Dynamic RAM)

- Capacitor में charge के रूप में data store होता है।
- Slower than SRAM.
- Cheaper and higher capacity.
- Periodic refresh required.
- Main memory में उपयोग होता है।

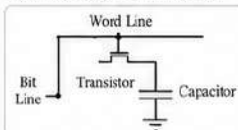


Fig. 3.5 DRAM Cell (Using Capacitor)

SRAM and DRAM में अंतर

Feature	SRAM	DRAM
Full Form	Static RAM	Dynamic RAM
Storage Element	Flip-Flop	Capacitor
Speed	Faster	Slower
Cost per Bit	Higher	Lower
Refresh	Not required	Required periodically
Capacity	Lower	Higher
Use	Cache memory	Main memory (RAM)

2. Classification of Memory

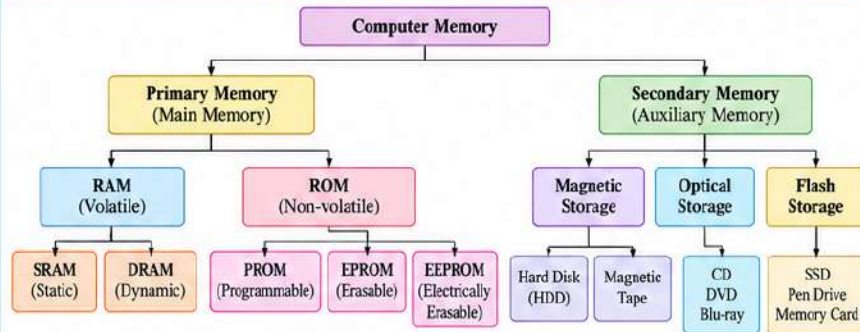


Fig. 3.2 Classification of Computer Memory

3.2 ROM (Read Only Memory)

- Non-volatile memory (power off पर भी data सुरक्षित रहता है)।
- Mostly read-only।
- Firmware (BIOS) और boot instructions store करती है।



Fig. 3.6 Types of ROM

4. Secondary Memory (द्वितीयक मेमोरी)

Secondary memory वह मेमोरी है जिसमें data और programs को permanent रूप से store किया जाता है। यह non-volatile होती है और CPU इसे directly access नहीं करता है। इसकी storage capacity बहुत अधिक होती है और cost per bit कम होती है।

4.1 Types of Secondary Memory



Fig. 3.7 Examples of Secondary Memory

4.2 Hard Disk Structure

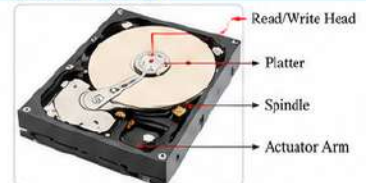


Fig. 3.8 Hard Disk Drive (HDD) - Internal View

4.3 Comparison: Primary vs Secondary Memory

Feature	Primary Memory	Secondary Memory
CPU Access	Directly accessible	Indirect access
Speed	Faster	Slower
Capacity	Smaller	Larger
Cost per Bit	Higher	Lower
Volatility	RAM: Volatile ROM: Non-volatile	Non-volatile
Purpose	Current processing	Long-term storage
Examples	RAM, ROM	HDD, SSD, CD/DVD, Pen Drive, Magnetic Tape

4.4 Uses of Secondary Memory

- Permanent storage of data and programs.
- Backup and archival purpose.
- Large storage capacity.
- Storage of operating system, application software, documents, etc.

3.7 CACHE MEMORY (5 Marks)

1. Introduction (परिचय)

Cache memory एक बहुत ही high-speed memory होती है जो CPU और main memory (RAM) के बीच रखी जाती है। यह frequently used data और instructions को store करती है ताकि CPU को बार-बार main memory से data न लेना पड़े और access time कम हो जाये।

Definition (परिभाषा)

Cache memory is a small, very fast memory located between the CPU and RAM that stores frequently used data and instructions to reduce access time.

Cache memory एक छोटी, बहुत तेज गति वाली memory है जो CPU और RAM के बीच स्थित होती है और frequently used data तथा instructions को store करती है जिससे access time कम हो जाता है।

2. Need of Cache Memory

- CPU, RAM की तुलना में बहुत तेज होता है।
- Cache memory, CPU और main memory के बीच speed gap को कम करती है।
- यह processing speed को improve करती है।
- यह CPU के waiting time को reduce करती है।

3. Position of Cache Memory

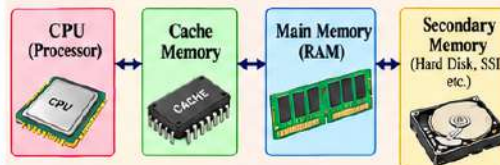


Fig. 3.1 Position of Cache Memory in Computer System

4. Working of Cache Memory

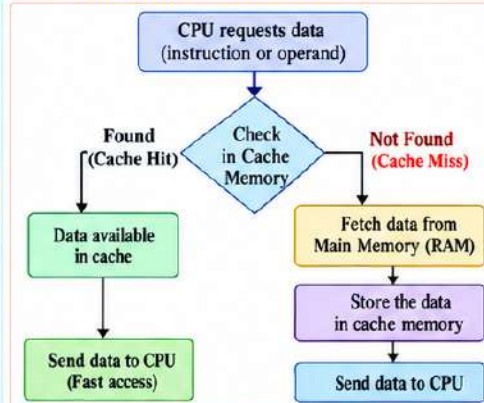


Fig. 3.2 Working of Cache Memory

5. Cache Hit and Cache Miss

5.1 Cache Hit

- जब requested data cache memory में मिल जाता है तो इसे Cache Hit कहते हैं।
- Data जल्दी मिल जाता है और CPU को wait नहीं करना पड़ता।
- Access time बहुत कम होता है।

Cache Hit = Fast Access

5.2 Cache Miss

- जब requested data cache memory में नहीं मिलता है तो इसे Cache Miss कहते हैं।
- Data को main memory (RAM) से fetch किया जाता है।
- फिर उसे cache memory में store किया जाता है ताकि अगली बार fast access हो सके।
- Access time ज्यादा होता है।

Cache Miss = Slower Access

6. Levels of Cache Memory

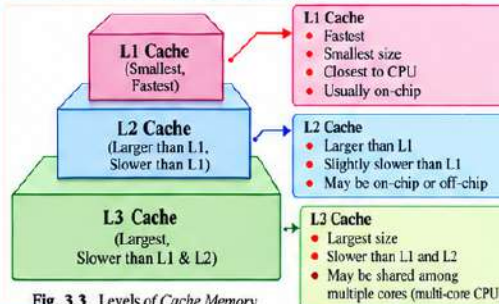


Fig. 3.3 Levels of Cache Memory

7. Characteristics / Features

- Very high speed.
- Small capacity.
- Expensive (cost per bit high).
- Volatile memory (data lost when power is off).
- Built using SRAM (Static RAM).
- Stores frequently used data and instructions.



8. Cache Memory vs RAM

Feature	Cache Memory	RAM (Main Memory)
Speed	Very high speed	Slower than cache
Capacity	Small (KB to MB)	Large (GB)
Cost per Bit	Higher (expensive)	Lower (cheaper)
Purpose	Stores frequently used data and instructions	Stores all running programs and data
Location	Between CPU and RAM (on-chip/off-chip)	Main memory, connected to CPU
Technology	SRAM	DRAM (Dynamic RAM)

9. Advantages of Cache Memory

- Faster execution of instructions and data.
- Reduces access time for frequently used data.
- Improves overall CPU performance.
- Reduces frequency of access to main memory (RAM).



L1 Cache (on CPU chip)



L2 / L3 Cache (on motherboard or processor)

10. Conclusion

Cache memory CPU और main memory के बीच एक बहुत तेज, छोटी परंतु महंगी memory है जो frequently used data और instructions को store करती है। यह access time कम करती है, CPU की performance को improve करती है और overall system की speed को बढ़ाती है।

3.10 VIRTUAL MEMORY

(5 Marks)

1. Introduction (परिचय)

Virtual memory is a memory management technique in which a part of the secondary storage (hard disk/SSD) is used as an extension of primary memory (RAM).

Virtual memory वह तकनीक है जिसमें secondary storage का एक भाग प्राथमिक मेमोरी (RAM) के विस्तार (extension) के रूप में उपयोग किया जाता है। यह तकनीक operating system द्वारा manage की जाती है।

2. Need of Virtual Memory (आवश्यकता)

- Primary memory (RAM) limited होती है।
- बड़े आकार के programs को चलाने के लिए अधिक memory की आवश्यकता होती है।
- Multiple programs को एक साथ चलाने के लिए larger address space चाहिए।
- Virtual memory logical memory को physical memory से बड़ा दिखाने में मदद करती है।
- यह better memory utilization और efficient multiprogramming प्रदान करती है।

3. Concept of Virtual Memory (संकल्पना)

Programmer के लिए एक large logical address space उपलब्ध कराया जाता है। Physical RAM से अधिक आवश्यक portion को temporary रूप से secondary storage (swap space / paging file) में रखा जाता है। जब जरूरत होती है, तो वह data secondary storage से RAM में load किया जाता है।

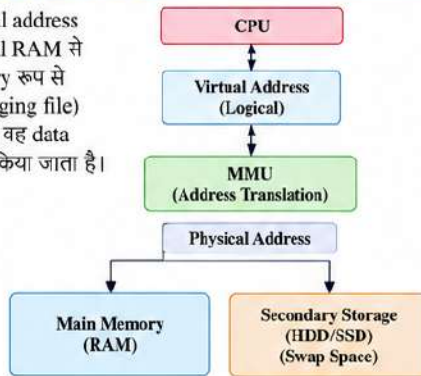


Fig. 3.10 Concept of Virtual Memory

4. Paging in Virtual Memory (पेजिंग)

Virtual memory को fixed size blocks में divide किया जाता है जिन्हें Pages कहते हैं।

Physical memory (RAM) को भी same size के blocks में divide किया जाता है जिन्हें Frames कहते हैं।

Page size = Frame size (usually 4 KB).

Key Terms

- **Page** : Virtual memory का block.
- **Frame** : Physical memory का block.
- **Page size** = Frame size.
- **Page Table** : Page to frame mapping table.

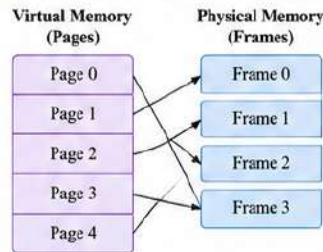


Fig. 3.11 Mapping of Pages to Frames

5. Page Table and Address Translation (पेज टेबल एवं पता अनुवाद)

Page Table एक data structure है जिसमें यह information होती है कि कोन-सा page किस frame में store है। MMU (Memory Management Unit) virtual address को physical address में translate करता है।

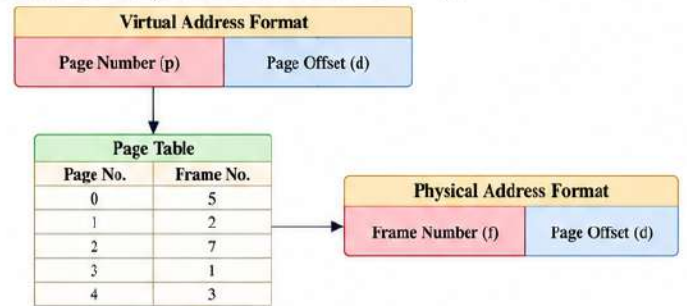


Fig. 3.12 Page Table and Address Translation

6. Page Fault (पेज दोष)

जब CPU किसी page को access करता है और वह page RAM में उपस्थित नहीं होता है, तो Page Fault occur होता है।

Operating system उस page को secondary storage से RAM में load करता है, page table को update करता है और instruction फिर से execute की जाती है।

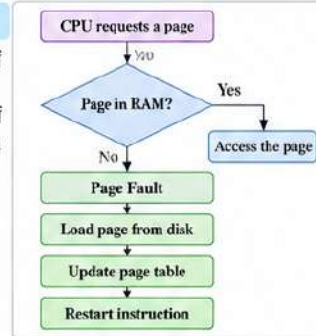


Fig. 3.13 Page Fault Handling

7. Advantages (लाभ)

- Large programs को run करने की सुविधा।
- Physical RAM से बड़ा logical memory space।
- Multiple programs एक साथ चला सकते हैं (multiprogramming)।
- Better memory utilization।
- Programmer के लिए memory management आसान।
- System performance improved (if page faults कम हों)।

8. Disadvantages (हानियाँ)

- Secondary storage RAM से बहुत slow होता है।
- अधिक page faults से system slow हो सकता है।
- Excessive paging से thrashing हो सकती है।
- Memory management complex हो जाता है।
- Disk का उपयोग होने से I/O overhead बढ़ जाता है।

9. Comparison: Physical Memory vs Virtual Memory

Feature	Physical Memory (Main Memory)	Virtual Memory
Location	RAM (hardware)	RAM + Secondary storage (hardware + OS)
Access time	Fast	Slower (disk access when page fault)
Capacity	Limited (e.g., 4 GB, 8 GB)	Large (e.g., 16 GB, 32 GB or more)
Controlled by	Hardware	Operating System (with MMU)
Visibility to user	Actual physical memory	Logical memory (larger than physical)
Cost	High	Lower (uses existing disk storage)
Volatility	RAM: Volatile	Uses non-volatile storage as extension
Purpose	Current processing	Run large programs and multiprogramming

4.8 VIRTUAL MEMORY (वर्चुअल मेमोरी)

(10 Marks)

1. Introduction (परिचय)

Virtual Memory एक memory management technique है, जो computer system को ऐसा illusion देती है कि उसके पास physical memory से भी अधिक memory उपलब्ध है। यह technique secondary storage (जैसे HDD/SSD) को एक extension के रूप में use करती है और उन program तथा data को manage करती हैं जो currently RAM में उपलब्ध नहीं हैं।

इसका मुख्य उद्देश्य है – limited primary memory को होते हुए भी large programs को run करना और efficient memory utilization करना।

Definition (परिभाषा)

Virtual memory वह memory है जो secondary storage को एक extension के रूप में use करके, एक logical address space provide करती है, जो physical memory से बड़ा होता है।

2. Need / Motivation (आवश्यकता)

- Physical memory (RAM) सीमित होती है।
- Large programs और data को एक address load करना संभव नहीं होता।
- CPU की speed बहुत अधिक है, जबकि RAM की speed कम है।
- Memory का बेहतर utilization करना।
- हर समय पूरे program को RAM में रखने की आवश्यकता नहीं होती।
- Multitasking और multi-programming को support करना।

3. Principle (सिद्धांत)

Virtual memory का सिद्धांत Locality of Reference पर अभिरत है। यानी जो data या instructions अभी use हो रहे हैं, वही RAM में रखे जाते हैं, बाकी data secondary storage में रहता है। जब आवश्यकता होती है तब page fault के माध्यम से उसे RAM में लाया जाता है।

4. Types of Virtual Memory (आभासी मेमोरी के प्रकार)

1. Demand Paging

- केवल जरूरत होने पर page को RAM में लाया जाता है।
- अनावश्यक pages load नहीं होते।
- Page fault होने पर page को secondary storage से load किया जाता है।
- यह most commonly used technique है।

2. Demand Segmentation

- पूरा segment (code, data, stack) की जरूरत पड़ने पर load होता है।
- हर segment का अलग logical address space होता है।
- यह program के logical structure के अनुसार काम करता है।

5. Working of Virtual Memory (कार्यप्रणाली)

- CPU किसी logical address को generate करता है।
- MMU (Memory Management Unit) उस address को physical address में convert करता है।
- यदि required page RAM में है → data सीधे RAM से मिल जाता है (Page Hit)।
- यदि page RAM में नहीं है → Page Fault होता है।
- OS secondary storage से page को load करता है और उसे RAM में place करता है।
- फिर process resume हो जाता है और data access हो जाता है।

6. Diagram (वर्चुअल मेमोरी की कार्यप्रणाली)

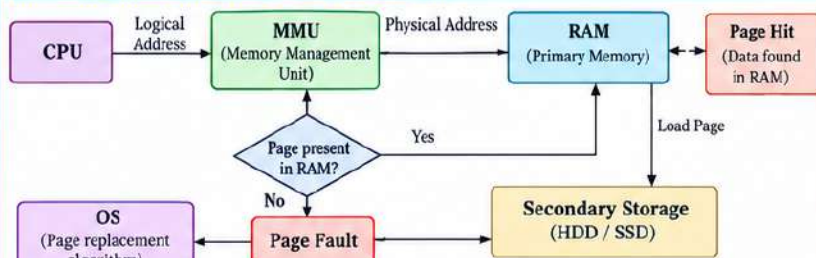


Fig. 4.8 Working of Virtual Memory

7. Page Fault Handling (पेज फॉल्ट हैंडलिंग)

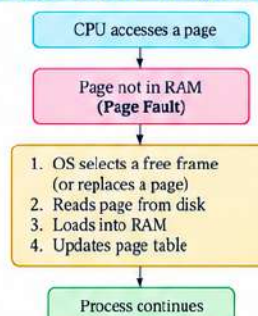


Fig. 4.9 Page Fault Handling

10. Advantages (लाभ)

- Large program size ko run karne ki facility.
- Physical memory ka efficient use.
- Memory utilization improve hota hai.
- Multitasking aur multiprogramming support.
- System performance better hota hai.
- Cost kam hoti hai (large memory ki requirement nahi hoti).

12. Comparison: Physical Memory vs Virtual Memory

Basis	Physical Memory	Virtual Memory
Size	Limited (e.g., 4 GB, 8 GB)	Larger (logical address space > physical)
Storage	RAM	RAM + Secondary Storage (HDD/SSD)
Access Time	Faster	Slower (due to page fault)
Cost	High	Lower (better utilization)
Program Size	Limited by RAM	Can be larger than RAM
Complexity	Simple	Complex (requires OS support)

8. Page Table (पेज टेबल)

Page table एक data structure है जो logical pages को physical frames से map करती है।

Page Table Example	
Page No.	Frame No.
0	5
1	2
2	7
3	1
4	3

Page table में valid/invalid bit भी होता है जो बताता है कि page RAM में है या नहीं।

9. Address Translation (एड्रेस ट्रांसलेशन)

CPU द्वारा generate किया गया logical address MMU के द्वारा page number और offset में divide किया जाता है। Page table से frame number प्राप्त करके physical address बनता है।

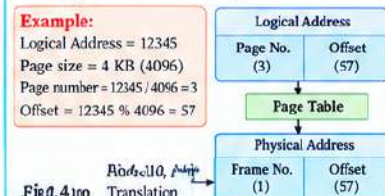


Fig. 4.10 Translation

13. Conclusion (निष्कर्ष)

Virtual Memory एक महत्वपूर्ण memory management technique है जो limited physical memory की समस्या को दूर करती है और large programs को run करने की सुविधा देती है। यह secondary storage का उपयोग करके memory का logical विस्तार करती है और system के performance और efficiency को बढ़ाती है।

Final Line: "Virtual memory provides a larger and efficient memory space by using secondary storage as an extension of primary memory."

3.8 DIRECT ACCESS STORAGE DEVICES (DASD)

(10 Marks)

1. Introduction (परिचय)

Direct Access Storage Devices (DASD) are secondary storage devices in which any data block can be accessed directly without reading the preceding data. These devices allow random access to data and are also called Random Access Storage Devices. Examples: Hard Disk Drive (HDD), Solid State Drive (SSD).

DASD ऐसे द्वितीयक भंडारण उपकरण हैं जिनमें किसी भी स्थान (ब्लॉक) को सीधे पहुँचा जा सकता है और डेटा को पढ़ने या लिखने के लिए पहले के डेटा को पढ़ने की आवश्यकता नहीं होती है। ये उपकरण यादृच्छिक (random) पहुँच प्रदान करते हैं।

Definition (परिभाषा)

Direct Access Storage Devices (DASD) are non-volatile storage devices in which any location can be accessed directly and data can be read or written without accessing the previous locations.

DASD वे गैर-वाष्पशील भंडारण उपकरण हैं जिनमें किसी भी स्थान को सीधे पहुँचाकर डेटा पढ़ा या लिखा जा सकता है, बिना पहले के स्थानों को पढ़े।

3. Types of DASD

The main types of DASD are:

1. **Hard Disk Drive (HDD)** – Magnetic storage device.
2. **Solid State Drive (SSD)** – Flash memory based device.
3. **Other direct access devices** – Pen drive, memory card, etc.

4. Hard Disk Drive (HDD)

HDD is a magnetic storage device in which data is stored on rotating platters coated with a magnetic material.

- Data is read and written by read/write head.
- It provides direct access to any track and sector.
- Large storage capacity and low cost per bit.

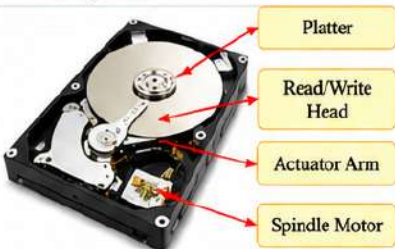


Fig. 3.11 Internal Structure of Hard Disk Drive (HDD)

5. Solid State Drive (SSD)

SSD is a semiconductor based storage device which uses NAND flash memory to store data. It has no moving mechanical parts.

- Faster than HDD.
- More reliable and shock resistant.
- Lower power consumption.
- Used in laptops, desktops and high-performance systems.

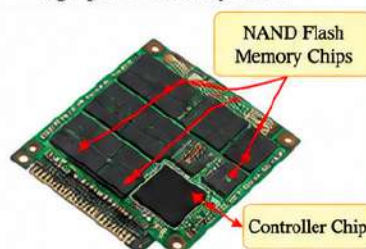


Fig. 3.12 Internal View of Solid State Drive (SSD)

8. Advantages of DASD

- Any data block can be accessed directly.
- Fast data retrieval.
- Large storage capacity.
- Supports both read and write operations.
- Suitable for online transaction processing and database applications.
- Data remains safe even when power is off (non-volatile).

2. Block Diagram of DASD

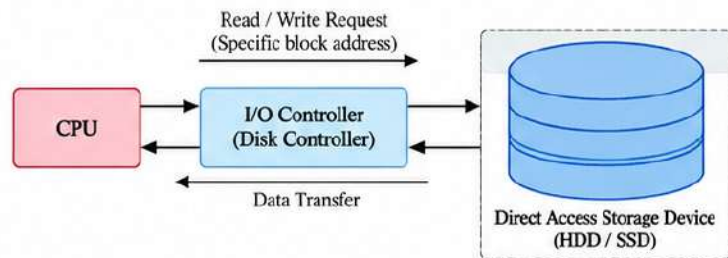


Fig. 3.10 Block Diagram of DASD

6. Working of DASD

In DASD, data is stored on specific physical addresses or blocks. When a read/write request is given, the disk controller directly moves the read/write head (in HDD) or accesses the required memory cells (in SSD) at the specified location and reads or writes the data without accessing the previous blocks.

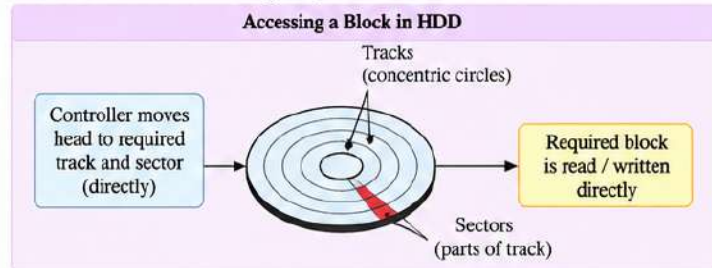


Fig. 3.13 Direct Access to a Block in HDD

7. Comparison: HDD vs SSD

Feature	Hard Disk Drive (HDD)	Solid State Drive (SSD)
Storage Technology	Magnetic platters	NAND flash memory
Access Time	Slower (ms)	Faster (µs)
Moving Parts	Yes (mechanical)	No (semiconductor)
Speed	Lower	Higher
Capacity	Very large (TB)	Large (GB-TB)
Cost per GB	Lower	Higher
Durability	Less (mechanical failure)	More (shock resistant)
Noise	Yes	No (silent)
Power Consumption	More	Less
Common Use	General storage, backup	High performance systems

9. Disadvantages of DASD

- Slower than primary memory (RAM).
- Cost per bit higher than magnetic tape.
- Physical damage can occur (especially in HDD).
- HDD has moving parts, so more chances of failure.
- Higher power consumption in HDD.
- SSD is more expensive than HDD.

3.8 DIRECT ACCESS STORAGE DEVICES (DASD)

(10 Marks)

1. Introduction (परिचय)

Direct Access Storage Devices (DASD) are secondary storage devices in which any data block can be accessed directly without accessing the preceding blocks. These devices provide random access to data and are also called Random Access Storage Devices.

प्रत्यक्ष अभिगम भंडारण उपकरण (DASD) वे द्वितीयक मेमोरी उपकरण हैं जिनमें किसी भी स्थान (ब्लॉक) को सीधे पढ़ा या लिखा जा सकता है। इन उपकरणों में डेटा को पढ़ने के लिए पहले के डेटा को पढ़ने की आवश्यकता नहीं होती है।

Examples: Hard Disk Drive (HDD), Solid State Drive (SSD).

2. Block Diagram of DASD

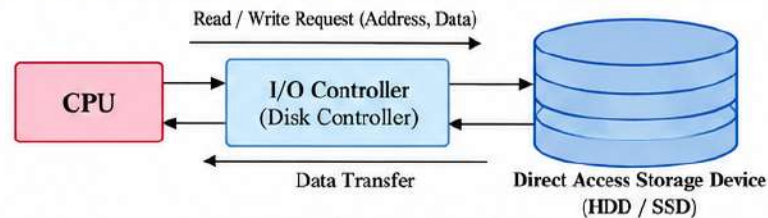


Fig. 3.8 Block Diagram of DASD Working

3. Characteristics (विशेषताएँ)

- Random (direct) access to any data block.
- Non-volatile storage (power off पर भी data सुरक्षित रहता है)।
- No need to read previous blocks.
- Large storage capacity.
- Faster access time as compared to sequential access devices (e.g., magnetic tape).
- Supports both read and write operations.
- Used for long-term storage of data, programs, files and operating system.
- Available in different forms such as HDD, SSD, etc.

4. Internal Structure of Hard Disk Drive (HDD)



Fig. 3.9 Internal Structure of Hard Disk Drive (HDD)

5. Working of Hard Disk Drive (HDD)

- Data is stored on magnetic platters.
- Platters rotate at high speed.
- Read/Write head moves radially to the required track using actuator arm.
- Data is organized in tracks and sectors.
- Any block can be accessed directly without reading the previous blocks.
- Controller manages read and write operations.

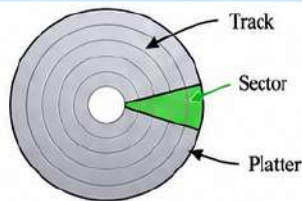


Fig. 3.10 Tracks and Sectors on Platter

6. Solid State Drive (SSD)

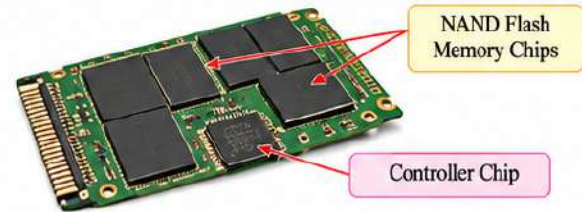


Fig. 3.11 Internal View of Solid State Drive (SSD)

7. HDD vs SSD (Difference)

Feature	Hard Disk Drive (HDD)	Solid State Drive (SSD)
Storage Technology	Magnetic platters	Flash memory (NAND)
Access Time	Slower (ms)	Faster (μ s)
Moving Parts	Yes (mechanical)	No (semiconductor)
Speed	Lower	Higher
Capacity	Very large (TB)	Large (GB-TB)
Cost per GB	Lower	Higher
Durability	Less (mechanical failure)	More (shock resistant)
Noise	Yes	No (silent)
Power Consumption	More	Less
Common Use	General storage, backup	High performance systems

8. Advantages of DASD

- Any data block can be accessed directly.
- Fast data retrieval.
- Large storage capacity.
- Supports read and write operations.
- Suitable for online transaction processing and database applications.
- Data remains safe even when power is off.
- Available in various forms (HDD, SSD, etc.).

9. Disadvantages of DASD

- Cost per bit higher than sequential devices (e.g., magnetic tape).
- HDD is slower than SSD.
- HDD has moving mechanical parts which may fail.
- SSD is more expensive than HDD.
- Power consumption is higher in HDD.
- Physical damage or shock can affect data (especially in HDD).

10. Conclusion (निष्कर्ष)

Direct Access Storage Devices (DASD) provide random access to data blocks and allow fast, direct reading and writing of data. Hard Disk Drive (HDD) and Solid State Drive (SSD) are the main examples of DASD. These devices are widely used for long-term storage due to their large capacity and non-volatile nature.

MEMORY MANAGEMENT UNIT (MMU)

(10 Marks)

1. Introduction (परिचय)

Memory Management Unit (MMU) is a hardware component of the CPU that manages the mapping of virtual addresses to physical addresses, controls access to memory and provides memory protection, relocation and memory management facilities.

मेमोरी मैनेजमेंट यूनिट (MMU) CPU का एक हार्डवेयर घटक है जो वर्चुअल एंड्रेस को फिजिकल एंड्रेस में मैप करता है तथा मेमोरी एक्सेस को नियंत्रित करता है, मेमोरी प्रोटेक्शन, रिलोकेशन और मेमोरी मैनेजमेंट की सुविधाएं प्रदान करता है।

Definition (परिभाषा)

MMU is a hardware unit that translates virtual addresses generated by the CPU into physical addresses, and manages memory access, protection, relocation and other memory-related functions.

MMU वह हार्डवेयर इकाई है जो CPU द्वारा उत्पन्न वर्चुअल एंड्रेस को फिजिकल एंड्रेस में परिवर्तित करती है और मेमोरी एक्सेस, प्रोटेक्शन, रिलोकेशन तथा अन्य मेमोरी संबंधी कार्यों का प्रबंधन करती है।

3. Functions of MMU

- **Address Translation** – Converts virtual address to physical address.
- **Memory Protection** – Restricts unauthorized access to memory.
- **Memory Relocation** – Allows a program to be loaded at any physical memory location.
- **Memory Management** – Supports virtual memory, paging and segmentation.
- **Cache Support** – Uses TLB to speed up address translation.
- **Access Control** – Checks read/write/execute permissions.
- **Handling Page Fault** – Generates page fault when required page is not in memory.

5. Virtual Address vs Physical Address

Feature	Virtual Address	Physical Address
Generated by	CPU	MMU (after translation)
Used in	Program execution	Actual memory access
Visibility	Seen by program	Seen by memory hardware
Size	May be larger than physical memory	Limited by physical memory size
Mapping	Translated by MMU	Actual location in main memory
Purpose	Provides logical view and abstraction	Used to access real memory cells

8. MMU with Paging (Example)

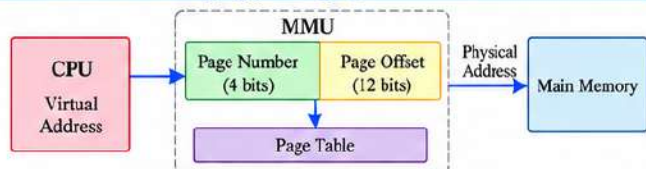
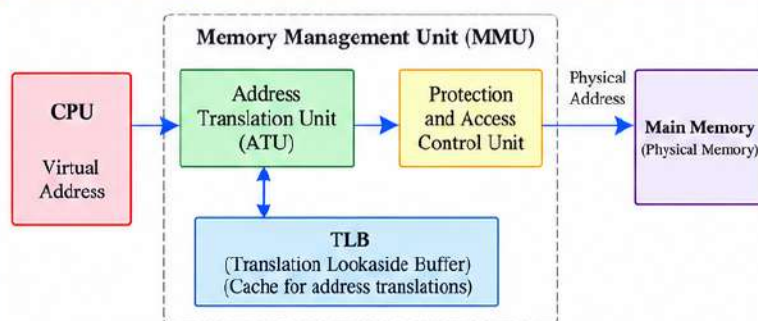


Fig. 2 Address Translation in Paging using MMU

2. Block Diagram of MMU



4. Address Translation Process

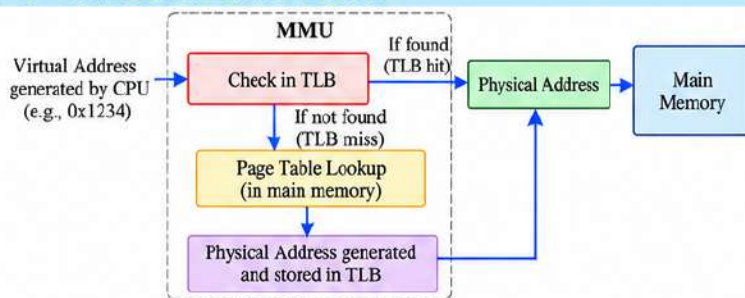
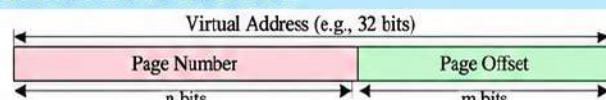


Fig. 1 Address Translation using MMU

6. Structure of a Virtual Address



7. Translation Lookaside Buffer (TLB)

- TLB is a small, fast associative memory inside the MMU.
- It stores recently used virtual-to-physical address mappings.
- It reduces the time of address translation.
- If the required entry is found in TLB, it is called a TLB hit.
- If not found, it is called a TLB miss and page table is searched in main memory.

9. Advantages of MMU

- Provides memory protection and access control.
- Supports virtual memory.
- Allows efficient memory utilization.
- Enables relocation of programs.
- Improves system security.
- Uses TLB to reduce translation time.
- Supports multitasking and multi-programming.

10. Conclusion (निष्कर्ष)

Memory Management Unit (MMU) plays a vital role in modern operating systems. It translates virtual addresses to physical addresses, ensures memory protection, supports virtual memory and improves efficient use of memory resources. MMU आधुनिक कंप्यूटर प्रणालियों में मेमोरी प्रबंधन का प्रमुख घटक है, जो वर्चुअल एंड्रेस को फिजिकल एंड्रेस में परिवर्तित करता है, मेमोरी सुरक्षा प्रदान करता है तथा वर्चुअल मेमोरी और प्रभावी मेमोरी उपयोग में महत्वपूर्ण भूमिका निभाता है।