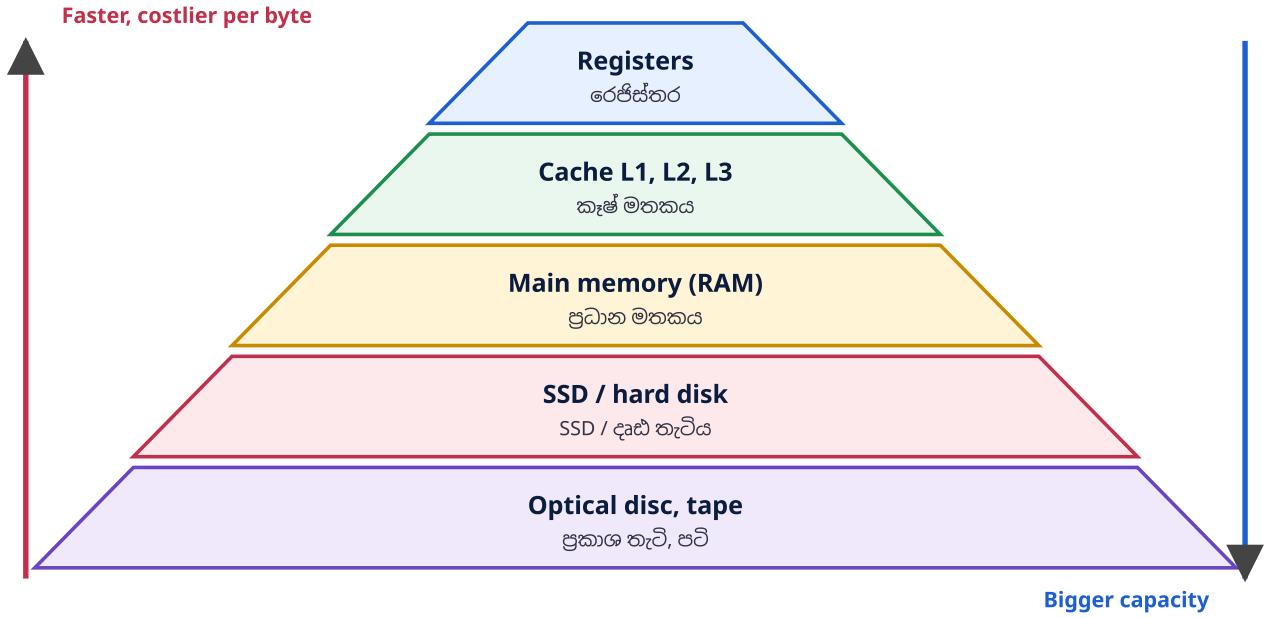
Grade 12 A/L ICT · Lesson 2

2.4 Memory Hierarchy: Registers, Cache, RAM, ROM and Secondary Storage

Syllabus 2.4. No single memory is fast, big and cheap at the same time. So a computer uses a **memory hierarchy**: a small amount of very fast, costly memory near the CPU, and large amounts of slower, cheaper memory further away. In this part you learn **why** we need the hierarchy, the **comparison criteria**, **volatile** memory (registers, cache, RAM – SRAM, DRAM, SDRAM), **non-volatile** memory (PROM, EPROM, EEPROM and secondary storage), and how to **compare** them by access time, cost per MB and capacity.

1. The memory hierarchy



Top: fastest, smallest, most costly. Bottom: slowest, largest, cheapest.

Think of a student's books: the page you are reading is in your hand (**registers**), a few books are on the desk (**cache**), more are on the shelf in the room (**RAM**), and the rest are in the library (**secondary storage**). What you use most is kept closest.

- **Why needed:** fast memory is very costly, so we cannot have gigabytes of it; cheap memory is slow. The hierarchy gives **speed close to the fastest level at a cost close to the cheapest**.
- It works because programs mostly reuse the **same data and nearby data** (locality), so copies kept in fast memory are used again and again.
- We also need **non-volatile** storage so data is not lost when the power goes off.

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

2. Comparison criteria

Criterion	Meaning
Physical size / density	How much data fits in a given space (bits per area)
Access method	Random (RAM), direct (disk) or sequential (tape)
Access time	Delay from asking for data to getting it
Capacity	How much data it can hold
Cost	Price per MB or GB
Volatility	Is data lost without power?
Location	Inside the CPU, on the motherboard, or outside
Physical arrangement	How bits are grouped into words (e.g. 8, 32 or 64 bits)

3. Volatile memory

Volatile memory loses its contents when the power is switched off.

Registers
Inside the CPU; fastest; hold only a few values being worked on now.

Cache memory
Fast SRAM between CPU and RAM that keeps copies of often used data. **L1** (smallest, fastest, in each core), **L2** (larger), **L3** (largest, shared by cores).

Main memory (RAM)
Holds the running programs and their data; random access; read and write.

Type of RAM	How it stores a bit	Features	Used for
SRAM (static)	Flip-flop of about 6 transistors	Very fast, no refresh, costly, low density	Cache memory
DRAM (dynamic)	Tiny capacitor + 1 transistor	Needs refreshing thousands of times a second; cheaper, high density, slower	Main memory
SDRAM (synchronous DRAM)	DRAM that works in step with the system clock	Faster than plain DRAM; DDR, DDR4, DDR5 are types of SDRAM	Modern PC RAM

4. Non-volatile memory

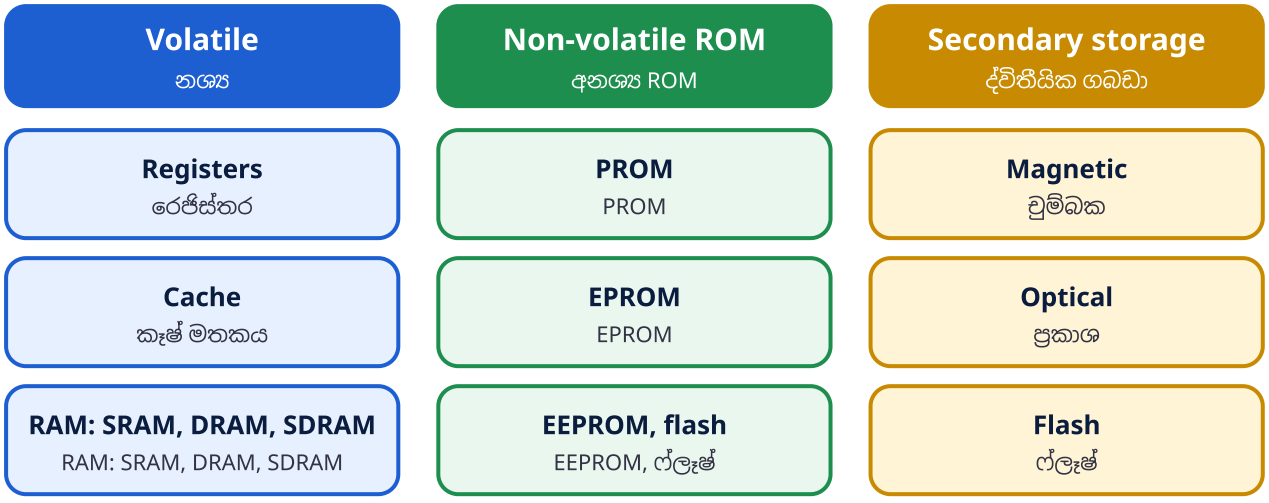
Non-volatile memory keeps its contents without power. ROM holds the start-up program (BIOS/UEFI firmware).

Type	How it is written	Can it be erased?

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

ROM (mask ROM)	Written at the factory	No
PROM	Blank; programmed **once** by the user with a special device	No – one time only
EPROM	Programmed electrically	Yes – whole chip erased by **ultraviolet light** through a quartz window, then reprogrammed
EEPROM	Programmed electrically inside the computer	Yes – **electrically**, byte by byte, without removing it; flash memory is a fast block-erase type

Secondary storage is non-volatile and large: **magnetic** (hard disk, tape), **optical** (CD, DVD, Blu-ray) and **flash** (SSD, memory cards, pen drives). It is not directly used by the CPU – data is first copied into RAM.



Volatile and non-volatile memory types.

5. Comparing the levels

Memory	Typical access time	Typical capacity	Cost per MB
Registers	< 1 ns	Bytes (a few hundred)	Highest
Cache (L1, L2, L3)	1–20 ns	KB to tens of MB	Very high
Main memory (RAM)	50–100 ns	4–64 GB	Medium
SSD (flash)	about 0.1 ms	256 GB – 4 TB	Low
Hard disk (HDD)	about 10 ms	1–20 TB	Very low
Optical disc / tape	100 ms to minutes	GB (disc) to TB (tape)	Lowest

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

🧱 **Worked example: A CPU finds data in cache 95% of the time (2 ns). Otherwise it reads RAM (80 ns). Using the simple model, what is the average access time?**
Average = 0.95 × 2 + 0.05 × 80 = 1.9 + 4.0 = **5.9 ns**. Much closer to cache speed than RAM speed – that is why cache helps.

🧱 **Worked example: A hard disk access takes 10 ms and RAM takes 50 ns. How many times slower is the hard disk?**
10 ms = 10,000,000 ns. 10,000,000 ÷ 50 = **200,000 times slower**.

🧱 **Worked example: A computer has 8 GB of byte-addressable RAM. How many bytes is that, and how many address lines are needed? How many 64-bit words does it hold?**
8 GB = 8 × 2^{30} = 2^{33} = **8,589,934,592 bytes**, so **33 address lines**. One 64-bit word = 8 bytes, so 8,589,934,592 ÷ 8 = **1,073,741,824 words**.

💡 Memory units here use powers of 2: 1 KB = 1024 bytes, 1 MB = 1024 KB, 1 GB = 1024 MB = 2^{30} bytes.

🚀 **Beyond the syllabus (2026 update)** *Not required for the exam – read for interest.* **DDR5, HBM and PCIe 5.0 SSDs.** In 2026 new PCs use **DDR5** SDRAM (about 4,800–8,000 MT/s), and phones use **LPDDR5X**. AI graphics chips stack DRAM layers on top of each other as **HBM3E** (high bandwidth memory) to feed thousands of cores. **PCIe 5.0 NVMe SSDs** read at about 14,000 MB/s, closing part of the gap between RAM and storage. New non-volatile ideas such as MRAM are being tested.

Key Words

Memory hierarchy – Arranging memory from small, fast and costly to large, slow and cheap.

Volatile memory – Memory that loses its contents when power is off.

Non-volatile memory – Memory that keeps its contents without power.

Cache memory – Small fast SRAM between the CPU and RAM holding often used data.

SRAM – Static RAM made of flip-flops; fast and needs no refresh.

DRAM – Dynamic RAM made of capacitors; must be refreshed.

SDRAM – DRAM synchronised with the system clock, e.g. DDR5.

PROM – ROM that the user can program only once.

EPROM – ROM erased with ultraviolet light and reprogrammed.

EEPROM – ROM erased and rewritten electrically inside the circuit.

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

Access time – The delay between asking for data and receiving it.

Random access – Any location can be reached in the same time.

Secondary storage – Large non-volatile storage such as disks and flash drives.

Word – A group of bits handled together by the CPU, e.g. 64 bits.

Refresh – Recharging DRAM cells regularly so data is not lost.

Sample Q&A

1. Why does a computer need a memory hierarchy?

> **Answer:** Fast memory is very costly and small, cheap memory is slow. Mixing levels gives speed near the fastest level at a cost near the cheapest, and non-volatile levels keep data without power.

2. Distinguish volatile and non-volatile memory with two examples each.

> **Answer:** Volatile memory loses data without power (registers, cache, RAM). Non-volatile keeps data (ROM, EEPROM, hard disk, SSD).

3. Compare SRAM and DRAM.

> **Answer:** SRAM uses flip-flops, needs no refresh, is fast and costly and is used for cache. DRAM uses capacitors, needs refreshing, is slower, cheaper and denser and is used for main memory.

4. How do PROM, EPROM and EEPROM differ?

> **Answer:** PROM can be programmed once only. EPROM is erased with ultraviolet light and reprogrammed. EEPROM is erased and rewritten electrically without removing it.

5. What is cache memory and why are there L1, L2 and L3 levels?

> **Answer:** Cache is fast SRAM that keeps copies of often used data near the CPU. L1 is smallest and fastest, L3 is larger and shared, so each level is a balance of speed and size.

6. List the levels from fastest to slowest.

> **Answer:** Registers, cache, main memory (RAM), SSD, hard disk, optical disc and tape.

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

MCQ

1. Which memory is the fastest?

A. RAM
B. Cache
C. Registers
D. SSD
E. Hard disk

2. Which is volatile?

A. DRAM
B. PROM
C. Hard disk
D. Blu-ray
E. EEPROM

3. Cache memory is usually made of:

A. PROM
B. EPROM
C. Magnetic tape
D. DRAM
E. SRAM

4. Which memory must be refreshed regularly?

A. PROM
B. DRAM
C. Registers
D. EPROM
E. SRAM

5. EPROM is erased using:

A. It cannot be erased
B. A magnet
C. Ultraviolet light
D. Electric signals byte by byte
E. A laser printer

6. ROM that can be programmed only once by the user is:

A. EPROM
B. EEPROM
C. SDRAM
D. PROM
E. Flash

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

7. Moving down the hierarchy, which INCREASES?

A. Closeness to the CPU
B. Speed
C. Cost per MB
D. Capacity
E. Volatility

8. With 95% cache hits at 2 ns and misses at 80 ns, the average access time (simple model) is:

A. 41 ns
B. 5.9 ns
C. 2 ns
D. 82 ns
E. 7.6 ns

9. DDR5 is a type of:

A. Optical disc
B. Register
C. EPROM
D. SRAM
E. SDRAM

10. How many address lines are needed for 8 GB of byte-addressable memory?

A. 33
B. 32
C. 8
D. 64
E. 30

11. A hard disk (10 ms) compared with RAM (50 ns) is about:

A. 2,000 times faster
B. 200,000 times slower
C. 200 times slower
D. 20 times slower
E. 5 times slower

12. The BIOS/UEFI start-up program is stored in:

A. The data bus
B. Registers
C. Non-volatile ROM or flash
D. DRAM
E. Cache

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

13. Which term means: “Arranging memory from small, fast and costly to large, slow and cheap”?

A. DRAM
B. Non-volatile memory
C. Access time
D. PROM
E. Memory hierarchy

14. Which term means: “Memory that loses its contents when power is off”?

A. Volatile memory
B. EPROM
C. Random access
D. Cache memory
E. SDRAM

15. Which term means: “Memory that keeps its contents without power”?

A. EEPROM
B. SRAM
C. Secondary storage
D. Non-volatile memory
E. PROM

16. Which term means: “Small fast SRAM between the CPU and RAM holding often used data”?

A. Access time
B. EPROM
C. DRAM
D. Cache memory
E. Word

17. Which term means: “Static RAM made of flip-flops; fast and needs no refresh”?

A. SDRAM
B. Random access
C. Refresh
D. EEPROM
E. SRAM

18. Which term means: “Dynamic RAM made of capacitors; must be refreshed”?

A. Secondary storage
B. DRAM
C. Memory hierarchy
D. PROM
E. Access time

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

19. Which term means: “DRAM synchronised with the system clock, e.g. DDR5”?

A. Random access
B. Word
C. SDRAM
D. EPROM
E. Volatile memory

20. Which term means: “ROM that the user can program only once”?

A. PROM
B. EEPROM
C. Secondary storage
D. Non-volatile memory
E. Refresh

Structured Questions

1. (a) Draw the memory hierarchy pyramid. (b) State how speed, capacity and cost change from top to bottom. *(4 marks)*

> (a) Registers, cache, RAM, secondary storage (SSD/HDD), off-line (optical/tape) in order; (b) speed falls; capacity rises; cost per MB falls.

2. Classify as volatile or non-volatile: SRAM, EEPROM, DRAM, PROM, hard disk, registers. *(2 marks)*

> Volatile: SRAM, DRAM, registers; non-volatile: EEPROM, PROM, hard disk.

3. Compare SRAM and DRAM under: (a) how a bit is stored (b) refresh (c) speed and cost (d) use. *(4 marks)*

> (a) SRAM flip-flop, DRAM capacitor; (b) SRAM none, DRAM needs refresh; (c) SRAM faster and costlier; (d) SRAM cache, DRAM main memory.

4. Cache hits 95% of the time at 2 ns; misses read RAM at 80 ns. (a) Find the average access time. (b) Why does cache improve performance? *(3 marks)*

> (a) 0.95 × 2 + 0.05 × 80 = 5.9 ns; (b) most data is found in fast cache because programs reuse nearby data; the CPU waits less for RAM.

5. Explain PROM, EPROM and EEPROM and give a use of EEPROM or flash. *(4 marks)*

> PROM programmed once; EPROM erased by ultraviolet light; EEPROM erased electrically in the circuit; use: BIOS/UEFI firmware updates or pen drives.

© 2026 schoolict.net (Ruwan Mangala Suraweera) · All rights reserved

Summary

- No memory is fast, large and cheap at once, so a hierarchy is used.
- Criteria: density, access method, access time, capacity, cost, volatility, location.
- Volatile: registers, cache (SRAM), main memory (DRAM, SDRAM).
- Non-volatile: PROM (once), EPROM (UV erase), EEPROM (electrical erase), and secondary storage.
- Going down: slower access, bigger capacity, lower cost per MB.
- Secondary storage is magnetic, optical or flash and is copied to RAM before use.

MCQ answer key – 2.4

1. **C** – Inside the CPU.
2. **A** – Loses data without power.
3. **E** – Fast, no refresh.
4. **B** – Capacitors leak charge.
5. **C** – Quartz window.
6. **D** – Programmable ROM.
7. **D** – Bigger and cheaper.
8. **B** – 1.9 + 4 = 5.9.
9. **E** – Synchronous DRAM.
10. **A** – 2^{33} bytes.
11. **B** – 10,000,000 ÷ 50.
12. **C** – Must survive power off.
13. **E** – Memory hierarchy – Arranging memory from small, fast and costly to large, slow and cheap.
14. **A** – Volatile memory – Memory that loses its contents when power is off.
15. **D** – Non-volatile memory – Memory that keeps its contents without power.
16. **D** – Cache memory – Small fast SRAM between the CPU and RAM holding often used data.
17. **E** – SRAM – Static RAM made of flip-flops; fast and needs no refresh.
18. **B** – DRAM – Dynamic RAM made of capacitors; must be refreshed.
19. **C** – SDRAM – DRAM synchronised with the system clock, e.g. DDR5.
20. **A** – PROM – ROM that the user can program only once.

© 2026 schoolict.net (Ruwan Mangala Suraweera). All rights reserved.