TUTORIAL #7	Semiconductor Memories, HDD and SSD. **Solutions**	(SC1006/Cx1106)

1. What is the difference between system and storage memory? Elaborate your answer with an example of a person working on his Laptop Computer, using a Power Point application from the Microsoft Office suite to draft his presentation slides.

[Suggested Solution]

System memory is the memory where the CPU execute the code and access the working copy of data during runtime.

Storage memory is where the computer stores the entire set of program and data. Majority of the time, storage memory do not support code execution.

In the example of a laptop, the system memory typically correspond to the DRAM connected to the processor. The entire Microsoft Office Suite will be too large to be store in the system memory so is likely to be stored in the Storage memory, which is the HDD or SSD in the laptop. During runtime, part of the power point application is loaded into the system for execution. Any data (photos, graphics, video etc) that is required to assemble the ppt slide would also need to be loaded into the system memory before the processor could perform any operation on it. Note that the data need not be the entire photo/video, only the subset that the processor works on need to be in the system memory at ay instance. The final ppt file is stored in the storage memory.

2. What memory type (SRAM, DRAM, NOR Flash, NAND Flash etc) would you use to implement the cache in Processor Cx1006-200M16 in the case study notes? Explain your choice.

[Suggested Solution]

SRAM. Cache needs to be implemented with very fast memory so as to keep up with the processor operating speed. DRAM is too slow and its transfer procedure too complex to be used for cache operation. Flash is not suitable due to its finite erase cycles and slower speed.

3. Name two main types of Flash memory available in the market. What are the differences between them? Which application/product areas are they used in?

[Suggested Solution]
NAND and NOR Flash Memory.
NAND:

- Data is accessed a page at a time. Command used to open a particular page followed by the individual bytes read/write. Does not support Execute in Place.
- More compact due to layout of the cells => more cost effective.
- Used mainly as storage memory. E.g. SSD, USB Flash Drive.

NOR:

- Allows Random Data Read by providing address information only.

- Supports Execute in Place. i.e. Code stored in NOR Flash can be executed directly without having to transfer to RAM first.
- Less compact than NAND flash.
- Used mainly as system memory to store program code.

4. Reference the two HDDs listed in the case study notes (HDD001 and HDD002)

   a. What is the **capacity** of each drive?

[Suggested Solution]

HDD001:

Capacity = 4*1024*128*512 = 268, 435, 456 Bytes = 256Mbytes.
Note: 1Mbyte = 2^20 bytes

HDD002:

Capacity = 8*1024*256*512 = 1, 073, 741, 824 bytes = 1GByte.

Note:

1GByte = 2^30 bytes,

# of cylinders = # of tracks of each surface,

# of heads = # of valid surfaces

   b. For HDD001,
      i. What is its **access time**?

[Suggested Solution]

RPS = 5000/60

Average rotational delay = $T_{R,AV}$ = 0.5/RPS = 0.5/(5000/60) = 6ms

Seek time = T_S = 5ms

Access time, $T_A = T_S + T_{R,AV} = 5 + 6 = 11$ms

      ii. What is the time needed to transfer a 4Kbyte file stored in random non-consecutive sectors on different tracks? Assume that every sector is on a different track.

[Suggested solution]
RPS = 5000/60 per second
Access time T_A = 11 ms

\# of sectors = 4*1024/512 = 8
Transfer time T_T for 1 sector = 512/(RPS*D_T*D_S) = 512/((5000/60)*128*512)
= 93.75 us
Total time, T_{TOTAL} = 8*(T_A + T_T) = 88.75 ms

Note: This illustrate the effect for HDD fragmentation. If a file is fragmented, i.e. stored in non-consecutive sectors/clusters, the effective performance of the HDD data transfer will drop, as shown by the total access time for the two examples above.

iii. After defragmenting HDD001, what would be the time needed to transfer a 280Kbyte file?

[Suggested solution]
Defragmentation => file is stored in consecutive sectors.

However, 280KByte is large than size of one track (128*512=64KByte).

It occupies 4 full tracks and 24 Kbyte on the fifth track.

RPS = 5000/60 per second
Access time T_A = 11 ms

T_T for one full track = 1/RPS = 12 ms

Total time for 1 track, T_{TOTAL} = 11+12 ms = 23 ms

4 tracks = 4*23 = 92ms

Last 24KByte:
Transfer time T_T = N/(RPS*DT*DS) = (24*1024)/((5000/60)*128*512) = 4.5 ms
Total time, T_{TOTAL} = 11+4.5ms = 15.5 ms

Total time needed to transfer 280KByte file = 92+15.5 = 107.5 ms

Note: T_A is required when moving from one track to the other since the R/W head need to be positioned at the starting sector of the next track.

c. If you are building a Network Access Storage for your home to act as a backup storage for your home's computers, which HDD would you choose? Justify your choice. MTTF in the HDD parameters refer to Mean-Time-To-Failure. It's a statistical approximation of how long a product could last before failing. Note that MTTF=1M hours doesn't mean the product's mean time to failure is 1M hours, but the larger MTTF value does indicate that the product is more reliable (statistically).

[Suggested Solution]
HDD002.

- Statistically more robust as MTTF = 1M hours, which is 2X that of HDD001. So less likely to fail.
- Higher storage
- Higher Performance (higher RPM, shorter Seek Time)
- HDD drives for NAS is usually more expensive (per bit wise) than typical consumer drives.

d. Would you use a SSD instead for Q4(c) above? Since SSD is more robust than HDD and robustness is very important for backup storage.

[Suggested Solution]

HDD.

- SSD is still has a higher cost per bit than HDD. Not ideal for application that requires huge storage, especially for consumer home use.
- Finite read/write cycles of SSD compared to HDD's almost infinite read/write cycles.
- SSD cannot replace HDD in backup storage area, including data centers and servers, yet. This primarily due to cost.

5. What would be the memory choices for the system and storage memory for each scenario below? Justify your memory choice selection in terms of functionality, performance and cost.
   a. Entry level Microsoft Windows desktop computer for general office use but needs huge data storage capacity to store videos relating to the company product.

[Suggested Solutions]

a. System Memory: DRAM, Storage Memory: Magnetic HDD
   - Entry level Desktop, General office use => low cost and only need average performance => DRAM and HDD as cost is lower than SSD
   - Desktop => No much physical movement expected so robustness to movement is not required.
   - Windows OS typically requires a few GByte of system memory. At this size, SRAM will be too expensive. Higher end product uses higher speed DRAM such as DDR3, DDR4 etc
   - Large storage for videos => Magnetic HDD (lower cost per bit than SSD)

6. The main active storage of Data Centers are HDD. But HDD is prone to crashing due to the mechanical nature of its design. How does these centers mitigate this issue?

[Solutions]

- Redundancy.
    - User data is stored in multiple servers at multiple sites. If one breaks down, the other would take over.
    - Within a server, some other error correction/recovery techniques may be used to mitigate localized error.
    - Data is also backup to tapes. This serves as the last line of defense.

(Not necessary to be covered during tutorial)

7. Why does the Processor Cx1006-200M16 has two different types of non-volatile memory (Flash and EEPROM) on-chip?

[Suggested Solution]

Flash has a larger page size (order of Kbytes) so can only be erased at Kbytes level. This is not suitable for certain use case such as storing of user configuration parameters, which is typically done at order of bytes level. An EEPROM, which has a smaller page size (tens of bytes) is more suitable for such use case as it result in less page erases. Also, EEPROM has a larger erase cycle endurance i.e. it could tolerate larger number of erasures before failing.