COMPUTER ORGANIZATION AND ARCHITECTURE

Course Code : CSE 2151

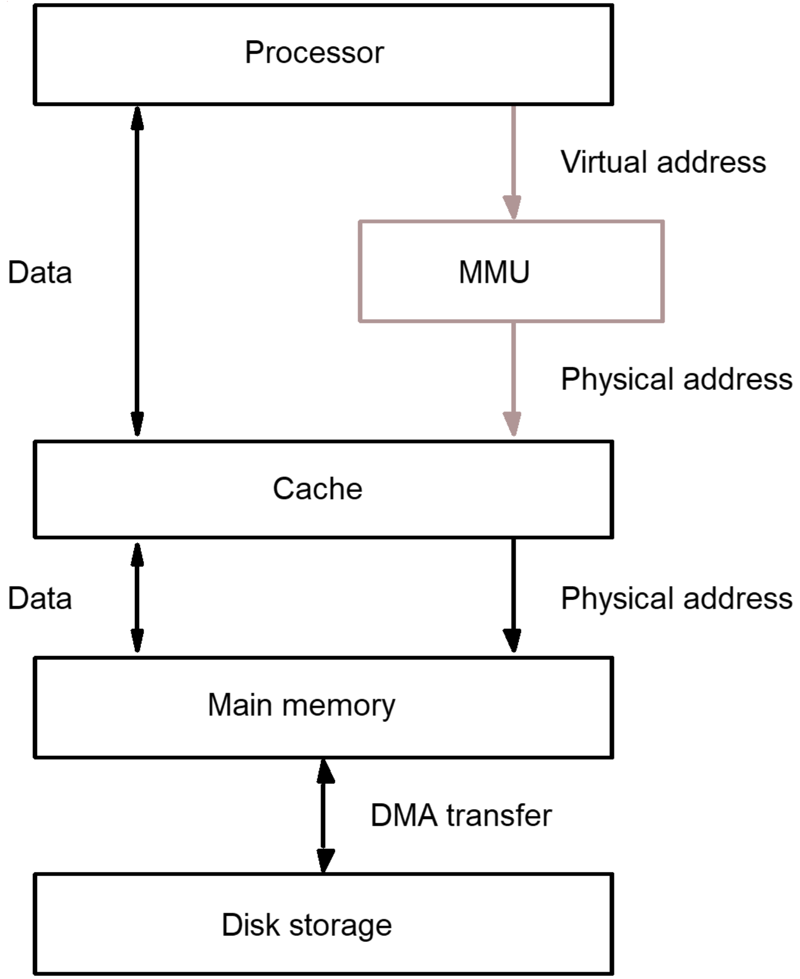
Credits : 04

VIRTUAL MEMORIES

- Physical main memory is not as large as the address space spanned by an address issued by the processor.

  $2^{32} = 4$ GB, $2^{64} = \ldots$

- When a program does not completely fit into the main memory, the parts of it not currently being executed are stored on secondary storage devices.
- Techniques that automatically move program and data blocks into the physical main memory when they are required for execution are called virtual-memory techniques.
- Virtual addresses will be translated into physical addresses.



Memory Management Unit

Figure 5.26. Virtual memory organization.

ADDRESS TRANSLATION

- All programs and data are composed of fixed-length units called pages, each of which consists of a block of words that occupy contiguous locations in the main memory.
- Page cannot be too small or too large.
- The virtual memory mechanism bridges the size and speed gaps between the main memory and secondary storage – like cache.
- Information about the main memory location of each page is kept in a page table.
  - includes the main memory address where the page is stored and the current status of the page
    - Validity, modified
- An area in the main memory that can hold one page is called a page frame.
- The starting address of the page table is kept in a page table base register.
- By adding the virtual page number to the contents of this register, the address of the corresponding entry in the page table is obtained.
- The contents of this location give the starting address of the page if that page currently resides in the main memory.

ADDRESS TRANSLATION

- The page table information is used by the MMU for every access, so it is supposed to be with the MMU.
- Since MMU is on the processor chip and the page table is rather large, only small portion of it, which consists of the page table entries that correspond to the most recently accessed pages, can be accommodated within the MMU.
- Translation Lookaside Buffer (TLB)

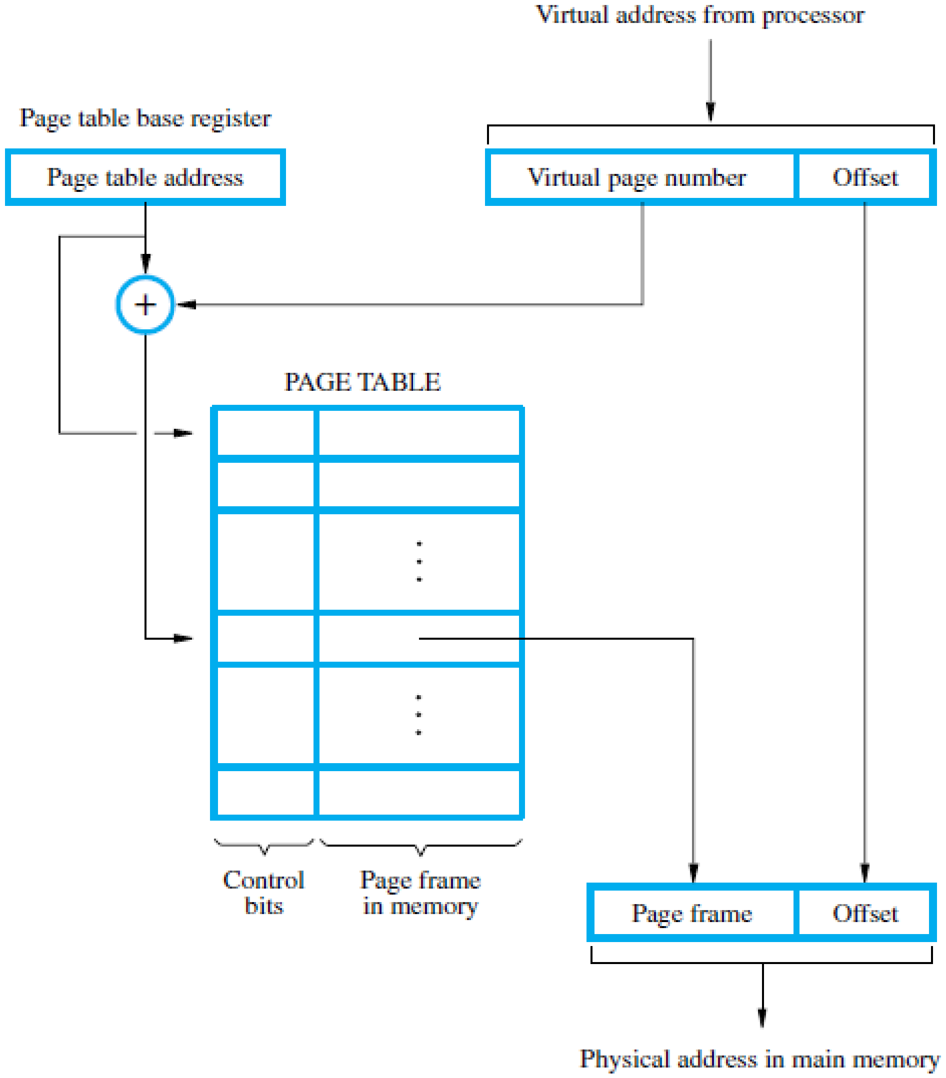


Figure 8.25 Virtual-memory address translation.

TRANSLATION PROCEDURE

- Given a virtual address, the MMU looks in the TLB for the referenced page. If the page table entry for this page is found in the TLB, the physical address is obtained immediately. If there is a miss in the TLB, then the required entry is obtained from the page table in the main memory and the TLB is updated.
- The contents of TLB must be coherent with the contents of page tables in the memory
- When the operating system changes the contents of a page table, it must simultaneously invalidate the corresponding entries in the TLB. One of the control bits in the TLB is provided for this purpose. When an entry is invalidated, the TLB acquires the new information from the page table in the memory as part of the MMU's normal response to access misses.
- Write-through is not suitable for virtual memory.
- Locality of reference in virtual memory

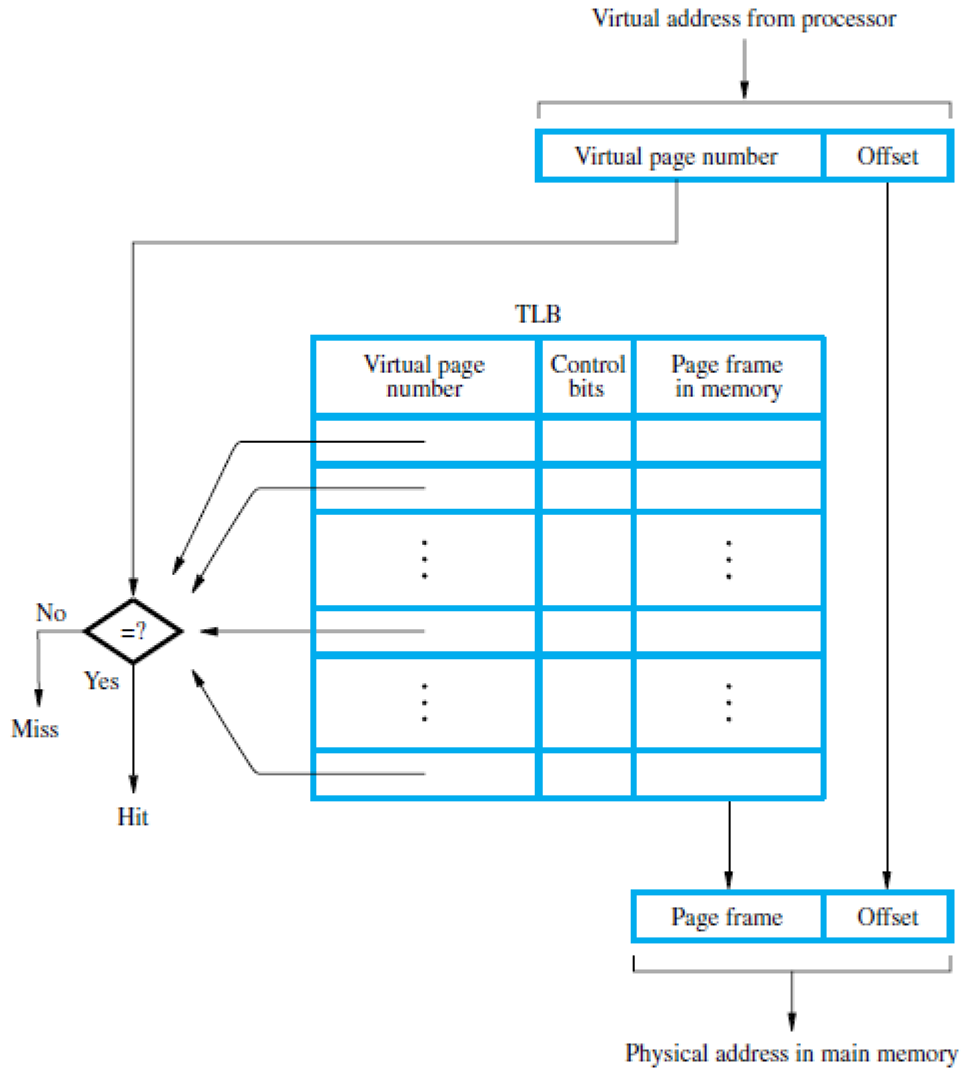


Figure 8.26 Use of an associative-mapped TLB.

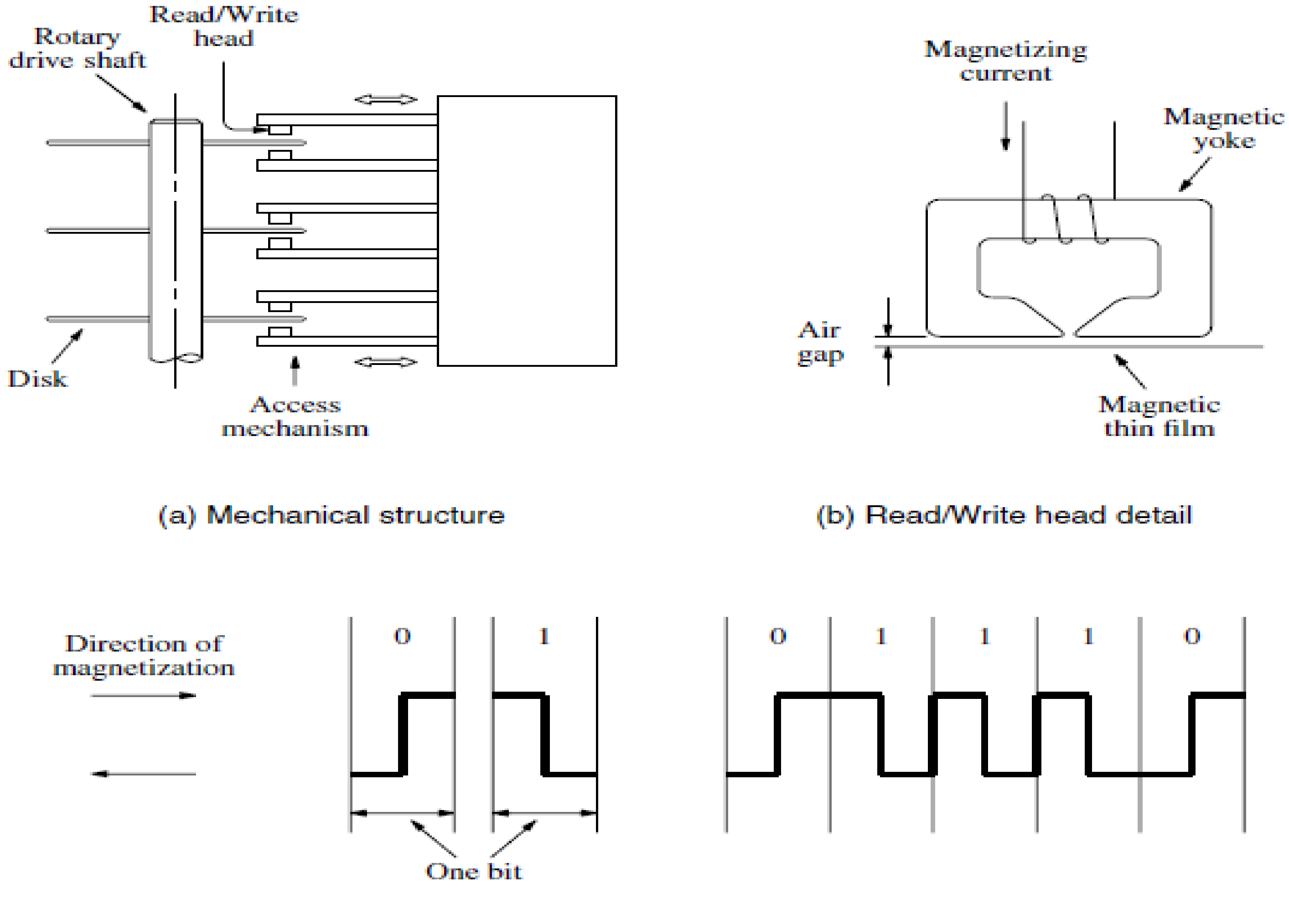
PAGE FAULT AND PAGE REPLACEMENT

- When a program generates an access request to a page that is not in the main memory, a page fault is said to have occurred.
- The entire page must be brought from the disk into the memory before access can proceed. When it detects a page fault, the MMU asks the operating system to intervene by raising an exception (interrupt).
- Page Replacement:
  - If a new page is brought from the disk when the main memory is full, it must replace one of the resident pages.
  - The problem of choosing which page to remove is just as critical here as it is in a cache, and the observation that programs spend most of their time in a few localized areas also applies.
  - Concepts similar to the LRU replacement algorithm can be applied to page replacement, and the control bits in the page table entries can be used to record usage history
  - A modified page has to be written back to the disk before it is removed from the main memory. It is important to note that the write-through protocol, which is useful in the framework of cache memories, is not suitable for virtual memory. The access time of the disk is so long that it does not make sense to access it frequently to write small amounts of data

SECONDARY STORAGE: MAGNETIC HARD DISKS

- One or more disk platters mounted on a common spindle.
- A thin magnetic film is deposited on each platter, usually on both sides.
- The assembly is placed in a drive that causes it to rotate at a constant speed.
- The magnetized surfaces move in close proximity to read/write heads
- Data are stored on concentric tracks
- Read/write heads move radially to access different tracks

SECONDARY STORAGE: MAGNETIC HARD DISKS

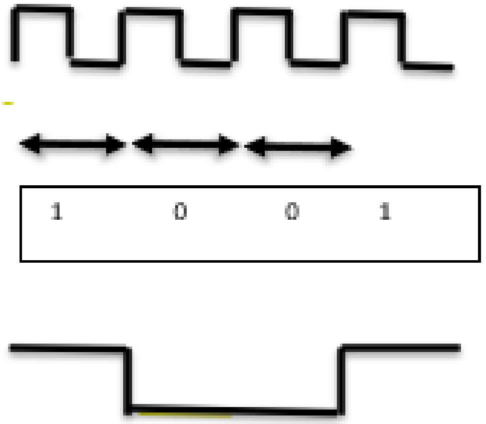


(a) Mechanical structure

(b) Read/Write head detail

(c) Bit representation by phase encoding

Figure 8.27 Magnetic disk principles.



READ WRITE HEAD

- Each read/write head consists of a magnetic yoke and a magnetizing coil.
- Digital information can be stored on the magnetic film by applying current pulses of suitable polarity to the magnetizing coil.
- This causes the magnetization of the film in the area immediately underneath the head to switch to a direction parallel to the applied field.
- The same head can be used for reading the stored information.
- Changes in the magnetic field in the vicinity of the head caused by the movement of the film relative to the yoke induce a voltage in the coil, which now serves as a sense coil.
- The polarity of this voltage is monitored by the control circuitry to determine the state of magnetization of the film.
- if the binary states 0 and 1 are represented by two opposite states of magnetization, a voltage is induced in the head only at 0-to-1 and at 1-to-0 transitions in the bit stream.
- A long string of 0s or 1s causes an induced voltage only at the beginning and end of the string.

PHASE ENCODING OR MANCHESTER ENCODING

- changes in magnetization occur for each data bit
- Clocking information is provided by the change in magnetization at the midpoint of each bit period.
- The drawback of Manchester encoding is its poor bit-storage density
- disks and the read/write heads are placed in a sealed,air-filtered enclosure.
- known as *Winchester technology*

MAGNETIC HARD DISK

- The disk system consists of three key parts.
- the assembly of disk platters- usually referred to as the disk.
- The Electromechanical mechanism that spins the disk and moves the read/write heads -called the disk drive
- the disk controller, which is the electronic circuitry that controls the operation of the system - may be implemented as a separate module, or it may be incorporated into the enclosure that contains the entire disk system

ORGANIZATION OF DATA ON A DISK

- Each surface is divided into concentric tracks, and each track is divided into sectors.
- The set of corresponding tracks on all surfaces of a stack of disks forms a logical cylinder
- All tracks of a cylinder can be accessed without moving the read/write heads.
- Data are accessed by specifying the surface number, the track number, and the sector number.
- Read and Write operations always start at sector boundaries.

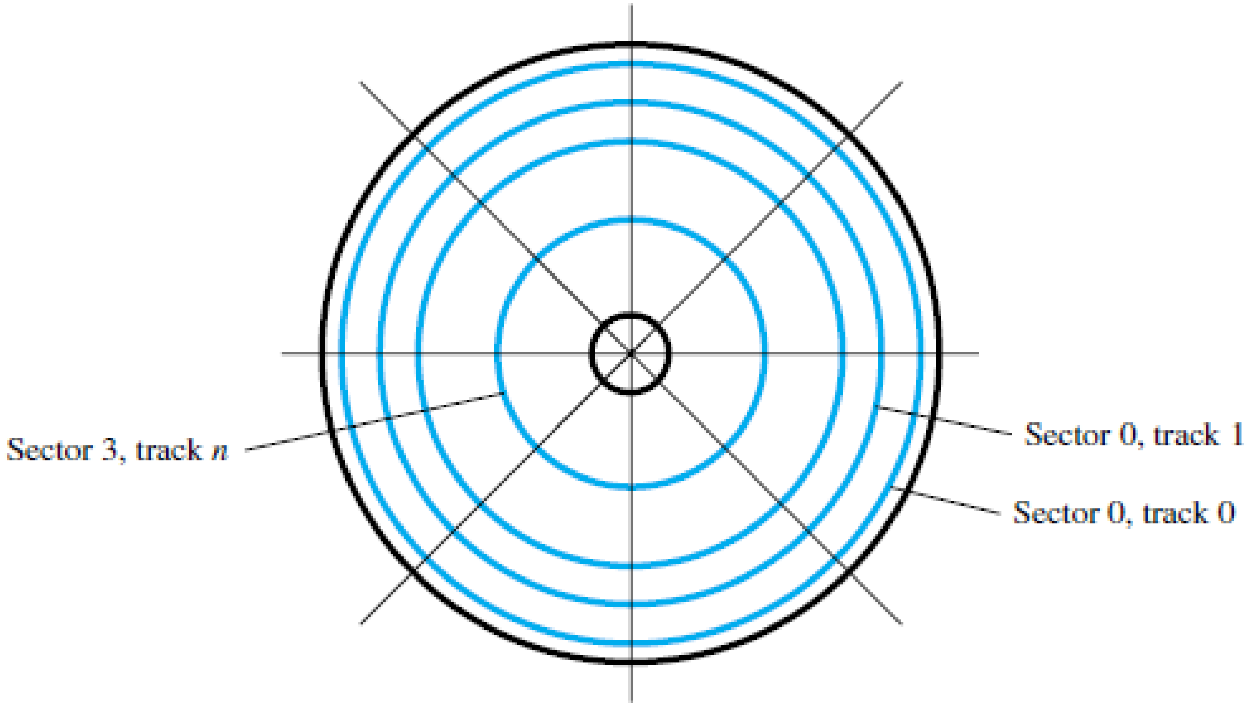


Figure 8.28 Organization of one surface of a disk.

ACCESS DATA ON A DISK

- Data bits are stored serially on each track
- Each sector may contain 512 or more bytes.
- Sector header-contains identification (addressing) information used to find the desired sector on the selected track
- Following the data, there is an error-correction code (ECC)-used to detect and correct errors that may have occurred in writing or reading the data bytes
- small inter-sector gap that enables the disk control circuitry to distinguish easily between two consecutive sectors.
- An unformatted disk has no information on its tracks.
- Formatting process writes markers that divide the disk into tracks and sectors. During this process, the disk controller may discover some sectors or even whole tracks that are defective. The disk controller keeps a record of such defects and excludes them from use.
- The formatting information comprises sector headers, ECC bits, and inter-sector gaps.
- The capacity of a formatted disk, after accounting for the formatting information overhead, is the proper indicator of the disk's storage capability.
- After formatting, the disk is divided into logical partitions

ACCESS DATA ON A DISK

- Each track has the same number of sectors, which means that all tracks have the same storage capacity.
- The stored information is packed more densely on inner tracks than on outer tracks
- also possible to increase the storage density by placing more sectors on the outer tracks, which have longer circumference
- Requires more complicated access circuitry.
- Access time
  - seek time -time required to move the read/write head to the proper track
  - rotational delay (latency)-time taken to reach the addressed sector after the read/write head is positioned over the correct track.

DATA BUFFER/CACHE

- Data buffer/cache -disk drive is connected to the rest of a computer system using some standard interconnection scheme, such as SCSI (Small Computer System Interface) or SATA (Serial Advanced Technology Attachment) usually capable of transferring data at much higher rates than the rate at which data can be read from disk tracks.
- Include a data buffer in the disk unit-to deal with difference in speed
- The buffer is a semiconductor memory, capable of storing a few megabytes of data. The requested data are transferred between the disk tracks and the buffer at a rate dependent on the rotational speed of the disk.
- Transfers between the data buffer and the main memory can then take place at the maximum rate allowed by the interconnect between them.

DISK CONTROLLER

- Operation of a disk drive is controlled by a disk controller circuit, which also provides an interface between the disk drive and the rest of the computer system.
- One disk controller may be used to control more than one drive.
- A disk controller that communicates directly with the processor contains a number of registers that can be read and written by the operating system.
- communication between the OS and the disk controller is achieved in the same manner as with any I/O interface
- The OS initiates the transfers by issuing Read and Write requests, which entail loading the controller's registers with the necessary addressing and control information.
- Typically, this information includes:
- Main memory address—The address of the first main memory location of the block of words involved in the transfer.
- Disk address—The location of the sector containing the beginning of the desired block of words.
- Word count—The number of words in the block to be transferred.

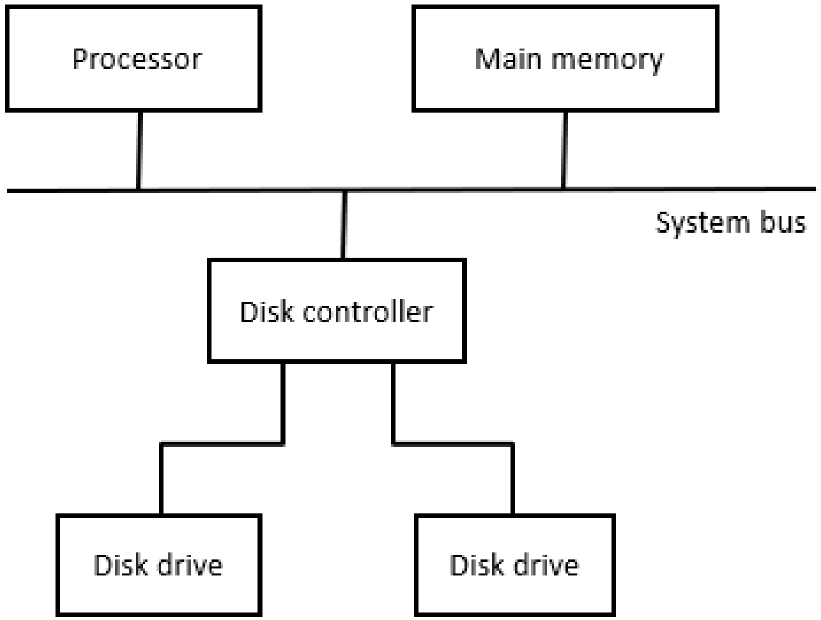


Figure 5.31. Disks connected to the system bus.

DISC CONTROLLER FUNCTIONS

- On the disk drive side, the controller's major functions are:
- Seek-Causes the disk drive to move the read/write head from its current position to the desired track.
- Read-Initiates a Read operation, starting at the address specified in the disk address register.
- Write-Transfers data to the disk
- Error checking-Computes the error correcting code (ECC) value for the data read from a given sector and compares it with the corresponding ECC value read from the disk

EXERCISE PROBLEM

- Consider a long sequence of accesses to a disk with an average seek time of 6 ms and an average rotational delay of 3 ms. The average size of a block being accessed is 8K bytes. The data transfer rate from the disk is 34 Mbytes/sec.
  a) Assuming that the data blocks are randomly located on the disk, estimate the average percentage of the total time occupied by seek operations and rotational delays.
  b) Repeat part (a) for the situation in which disk accesses are arranged so that in 90 percent of the cases, the next access will be to a data block on the same cylinder.

- Solution:

- It takes 8K/34M = 0.23 ms to transfer a block of data.

a. The total time needed to access each block is 6 + 3 + 0.23 = 9.23 ms. The portion of time occupied by seek and rotational delay is 9/9.23 = 0.97 = 97%.

b. In 90% of the cases, only rotational delays are involved. Therefore, the average time to access a block is $0.9 \times 3 + 0.1 \times 9 + 0.23 = 3.89$ ms.

   The portion of time occupied by seek and rotational delay is 3.6/3.89 = 0.92 = 92%.

EXERCISE PROBLEM

- A disk unit has 24 recording surfaces. It has a total of 14,000 cylinders. There is an average of 400 sectors per track. Each sector contains 512 bytes of data.
- (a) What is the maximum number of bytes that can be stored in this unit?
- (b) What is the data transfer rate in bytes per second at a rotational speed of 7200 rpm?

- Solution
- (a) The maximum number of bytes that can be stored on this disk is 24 X14000 X 400 X 512 = 68.8 X10^9 bytes.
- (b) The data transfer rate is (400 X 512 X7200)/60 = 24.58 X10^6 bytes/s.

TOPICS COVERED FROM

- Textbook 1:
  - Chapter 8: 8.8, 8.10, 8.10.1