Lecture 8 – I/O Device Management

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Objectives

- In this class we will discuss:
  - Types of I/O devices and the differences between them
  - How the management of I/O devices has developed over time
  - More detail on DMA
  - Buffering

Categories of I/O Devices

- **Human readable**
  - **Used to communicate with the user**
  - **Printers**
  - **Video display terminals**
    - **Display**
    - **Keyboard**
    - **Mouse**

Categories of I/O Devices

- **Machine readable**
  - Used to communicate with electronic equipment
  - Disk and tap drives
  - Sensors
  - Controllers
  - Actuators

Categories of I/O Devices

- **Communication**
  - Used to communicate with remote devices
  - Digital line drivers
  - Modems

Differences in I/O Devices

- **Data rate**
  - **May be differences of several orders of magnitude between the data transfer rates**

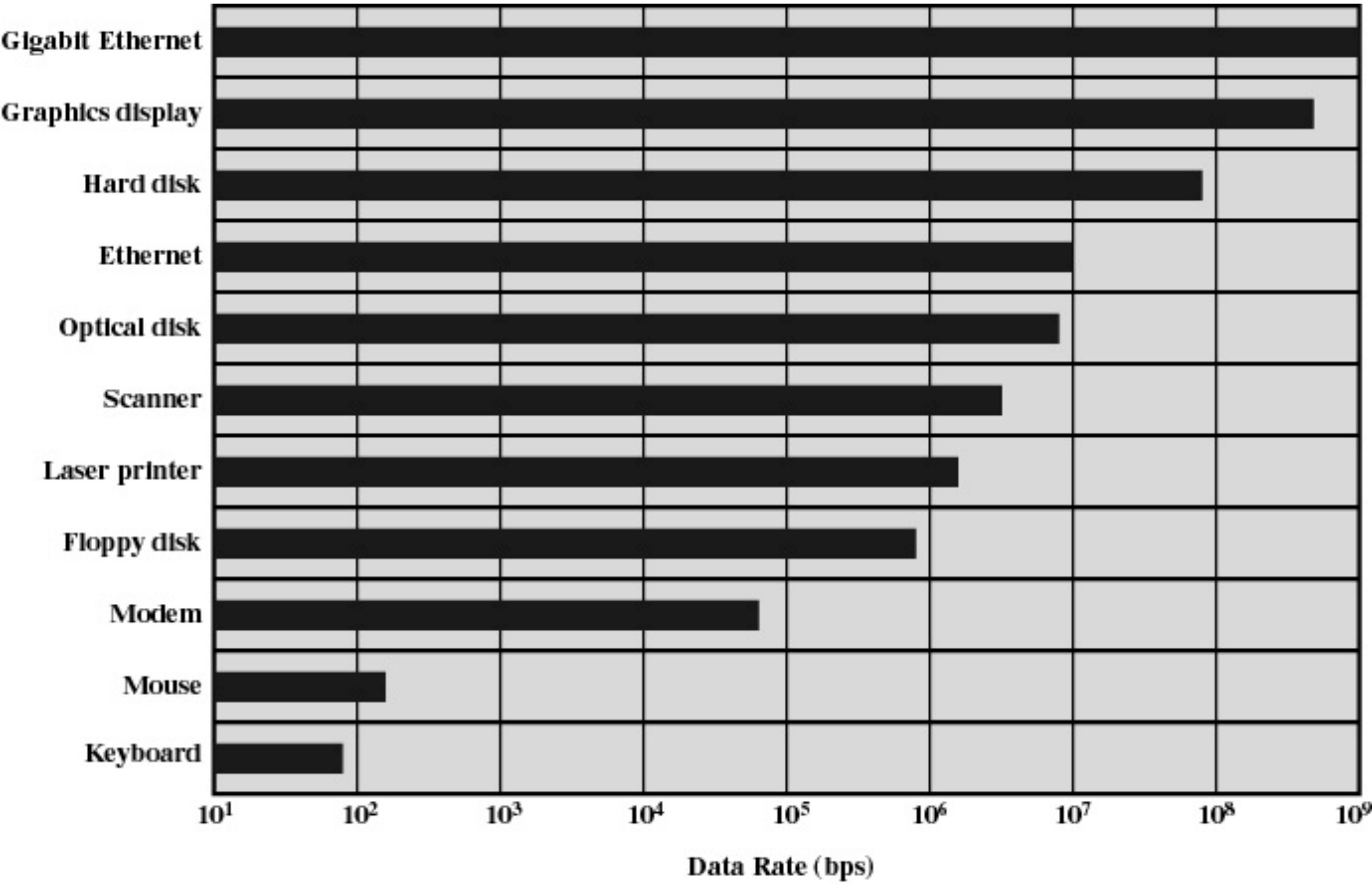

Figure 11.1 Typical I/O Device Data Rates

Differences in I/O Devices

- **Application**
  - **Disk used to store files requires file-management software**
  - **Disk used to store virtual memory pages needs special hardware and software to support it**
  - **Terminal used by system administrator may have a higher priority**

Differences in I/O Devices

- Complexity of control
- Unit of transfer
  - Data may be transferred as a stream of bytes for a terminal or in larger blocks for a disk
- Data representation
  - Encoding schemes
- Error conditions
  - Devices respond to errors differently

Differences in I/O Devices

- **Programmed I/O**
  - Process is busy-waiting for the operation to complete
- **Interrupt-driven I/O**
  - I/O command is issued
  - Processor continues executing instructions
  - I/O module sends an interrupt when done

Techniques for Performing I/O

- **Direct Memory Access (DMA)**
  - DMA module controls exchange of data between main memory and the I/O device
  - Processor interrupted only after entire block has been transferred

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Evolution of the I/O Function

- Processor directly controls a peripheral device
- Controller or I/O module is added
  - Processor uses programmed I/O without interrupts
  - Processor does not need to handle details of external devices

Evolution of the I/O Function

- **Controller or I/O module with interrupts**
  - **Processor does not spend time waiting for an I/O operation to be performed**
- **Direct Memory Access**
  - **Blocks of data are moved into memory without involving the processor**
  - **Processor involved at beginning and end only**

Evolution of the I/O Function

- **I/O module is a separate processor**
- **I/O processor**
  - **I/O module has its own local memory**
  - **Its a computer in its own right**

Direct Memory Access

- Takes control of the system form the CPU to transfer data to and from memory over the system bus
- Cycle stealing is used to transfer data on the system bus
- The instruction cycle is suspended so data can be transferred
- The CPU pauses one bus cycle
- No interrupts occur
  - Do not save context

DMA

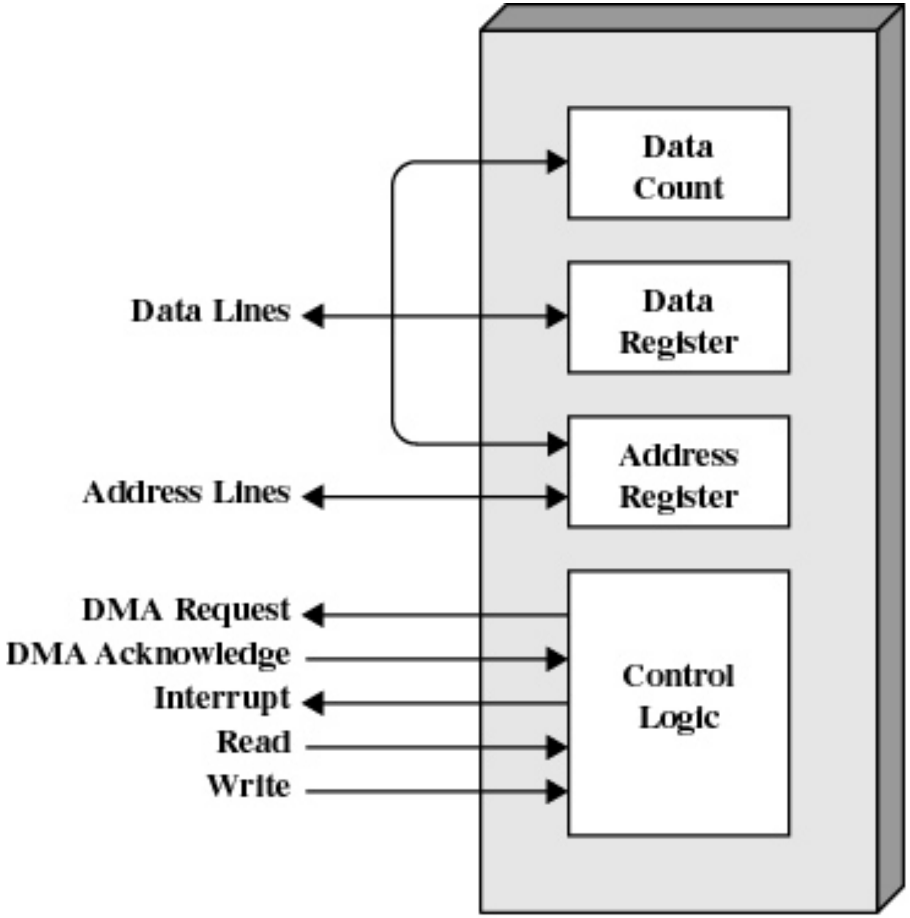


Figure 11.2 Typical DMA Block Diagram

DMA

- **Cycle stealing causes the CPU to execute more slowly**
- **Number of required busy cycles can be cut by integrating the DMA and I/O functions**
- **Path between DMA module and I/O module that does not include the system bus**

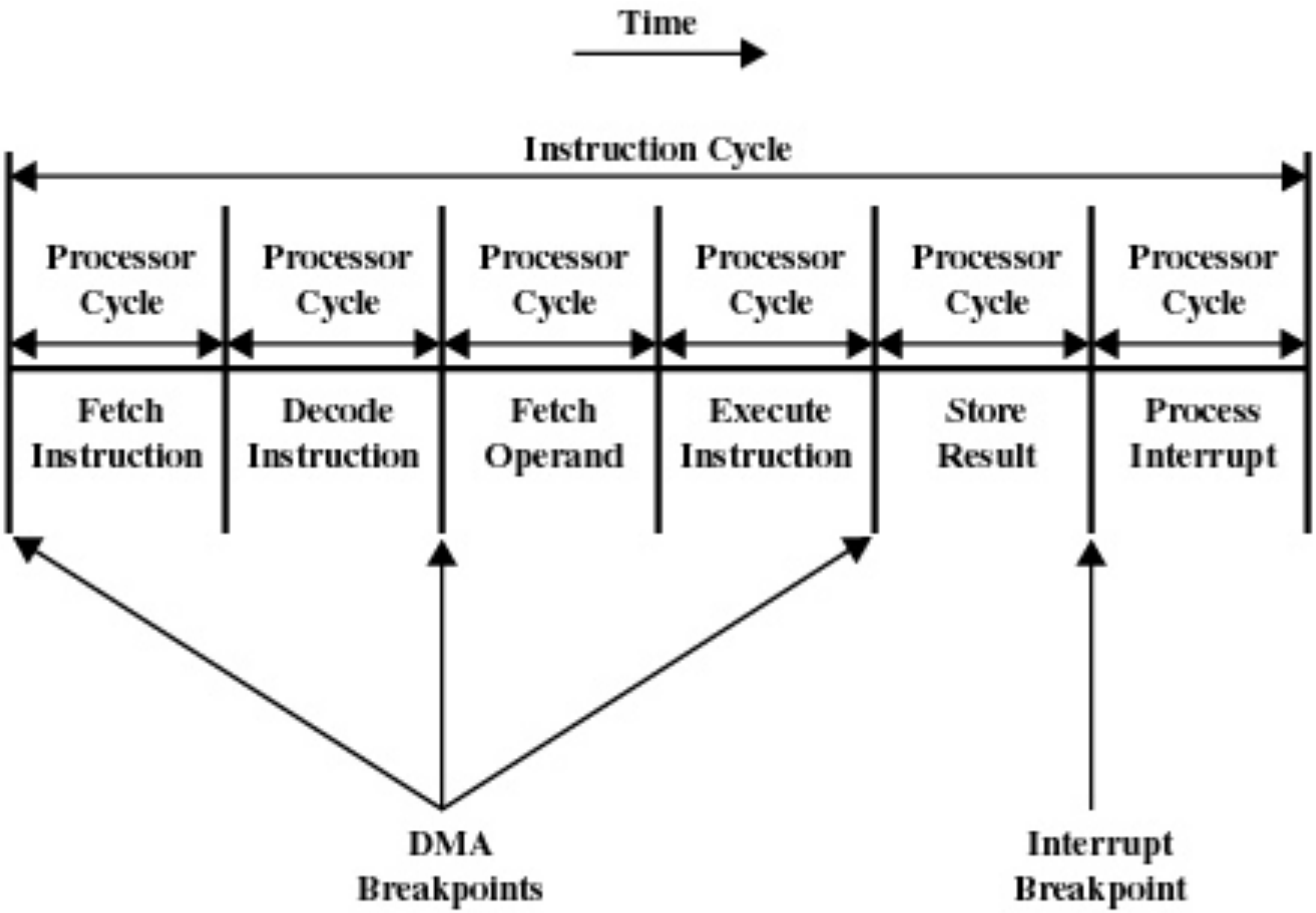
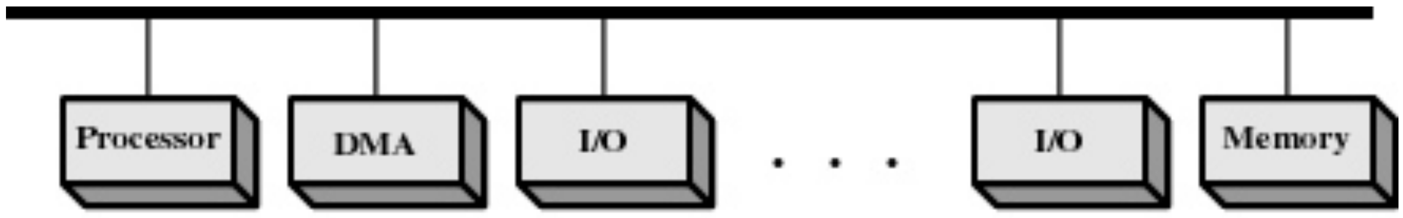


Figure 11.3 DMA and Interrupt Breakpoints During an Instruction Cycle

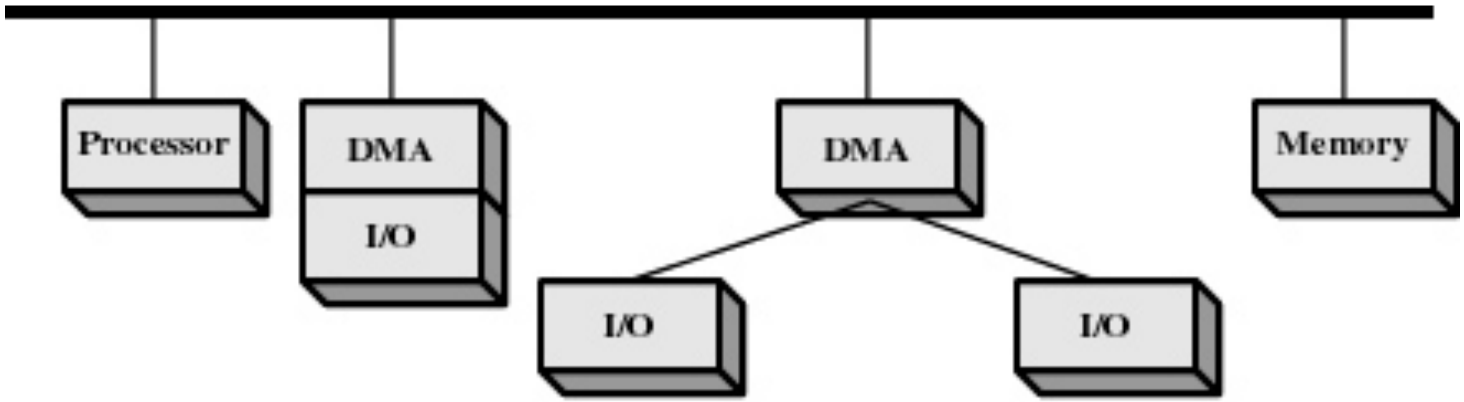
DMA



(a) Single-bus, detached DMA

Figure 11.4 Alternative DMA Configurations

DMA



(b) Single-bus, Integrated DMA-I/O

Figure 11.4 Alternative DMA Configurations

DMA

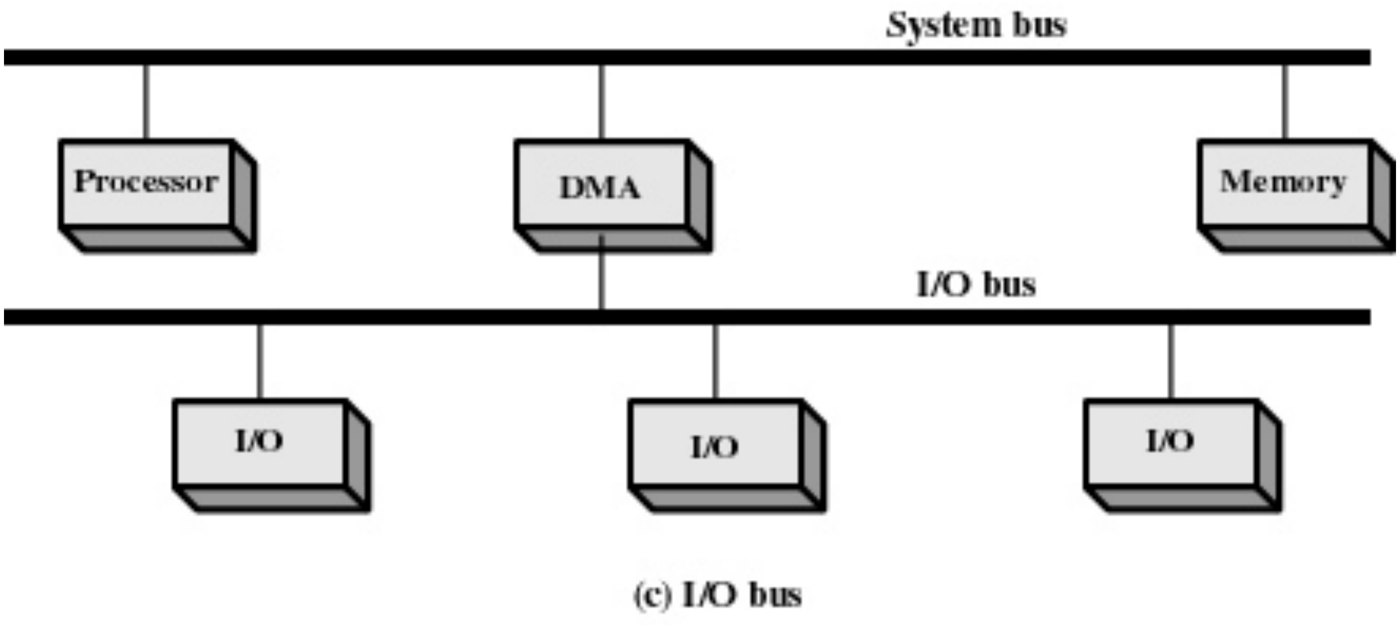


Figure 11.4 Alternative DMA Configurations

Operating System Design Issues

- Efficiency
  - Most I/O devices extremely slow compared to main memory
  - Use of multiprogramming allows for some processes to be waiting on I/O while another process executes
  - I/O cannot keep up with processor speed
  - Swapping is used to bring in additional Ready processes which is an I/O operation

Operating System Design Issues

- **Generality**
  - **Desirable to handle all I/O devices in a uniform manner**
  - **Hide most of the details of device I/O in lower-level routines so that processes and upper levels see devices in general terms such as read, write, open, close, lock, unlock**

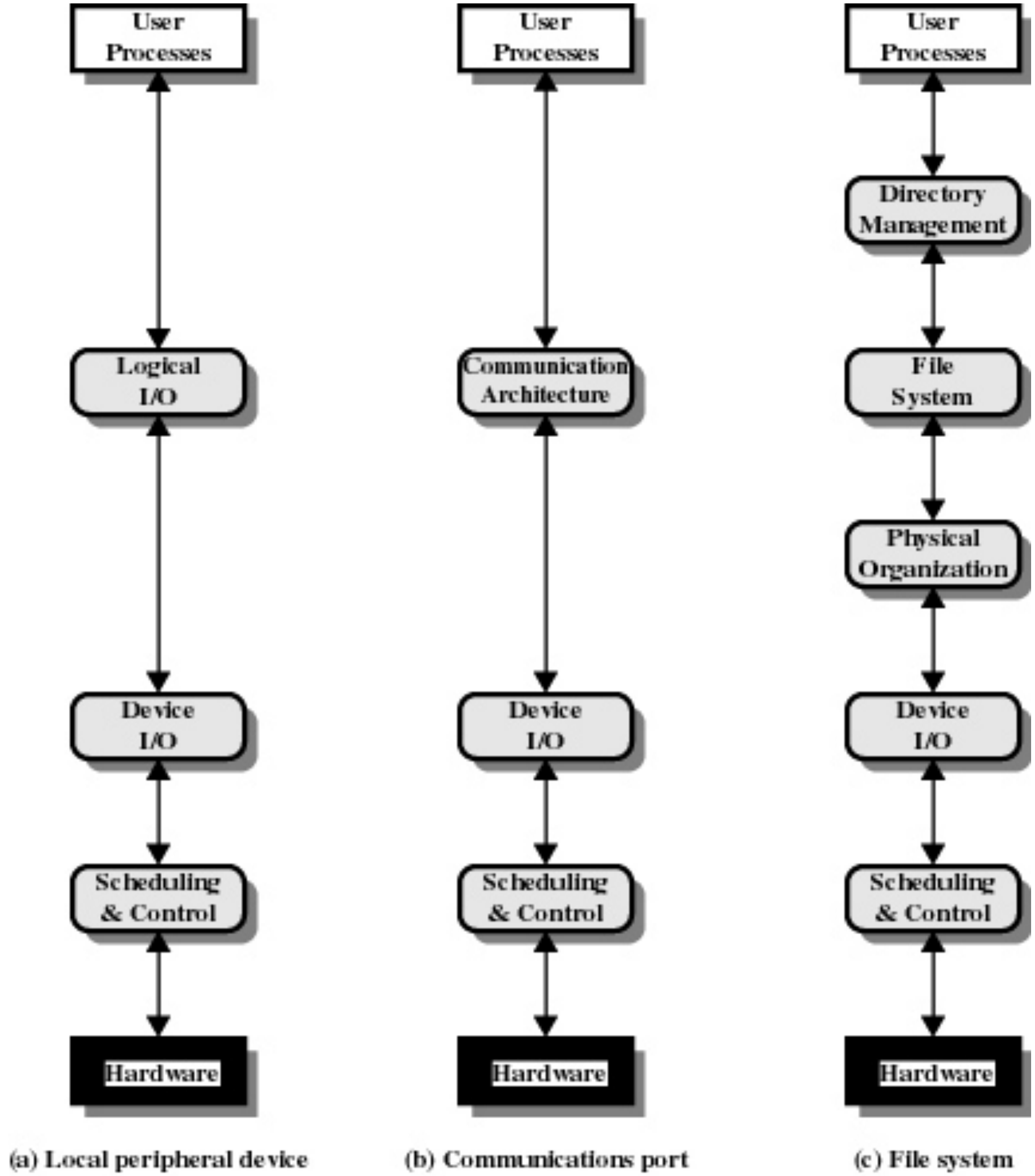


Figure 11.5 A Model of I/O Organization

I/O Buffering

- **Reasons for buffering**
  - **Processes must wait for I/O to complete before proceeding**
  - **Certain pages must remain in main memory during I/O**

I/O Buffering

- **Block-oriented**
  - Information is stored in fixed sized blocks
  - Transfers are made a block at a time
  - Used for disks and tapes
- **Stream-oriented**
  - Transfer information as a stream of bytes
  - Used for terminals, printers, communication ports, mouse, and most other devices that are not secondary storage

Single Buffer

- Operating system assigns a buffer in main memory for an I/O request
- Block-oriented
  - Input transfers made to buffer
  - Block moved to user space when needed
  - Another block is moved into the buffer
    - Read ahead

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I/O Buffering

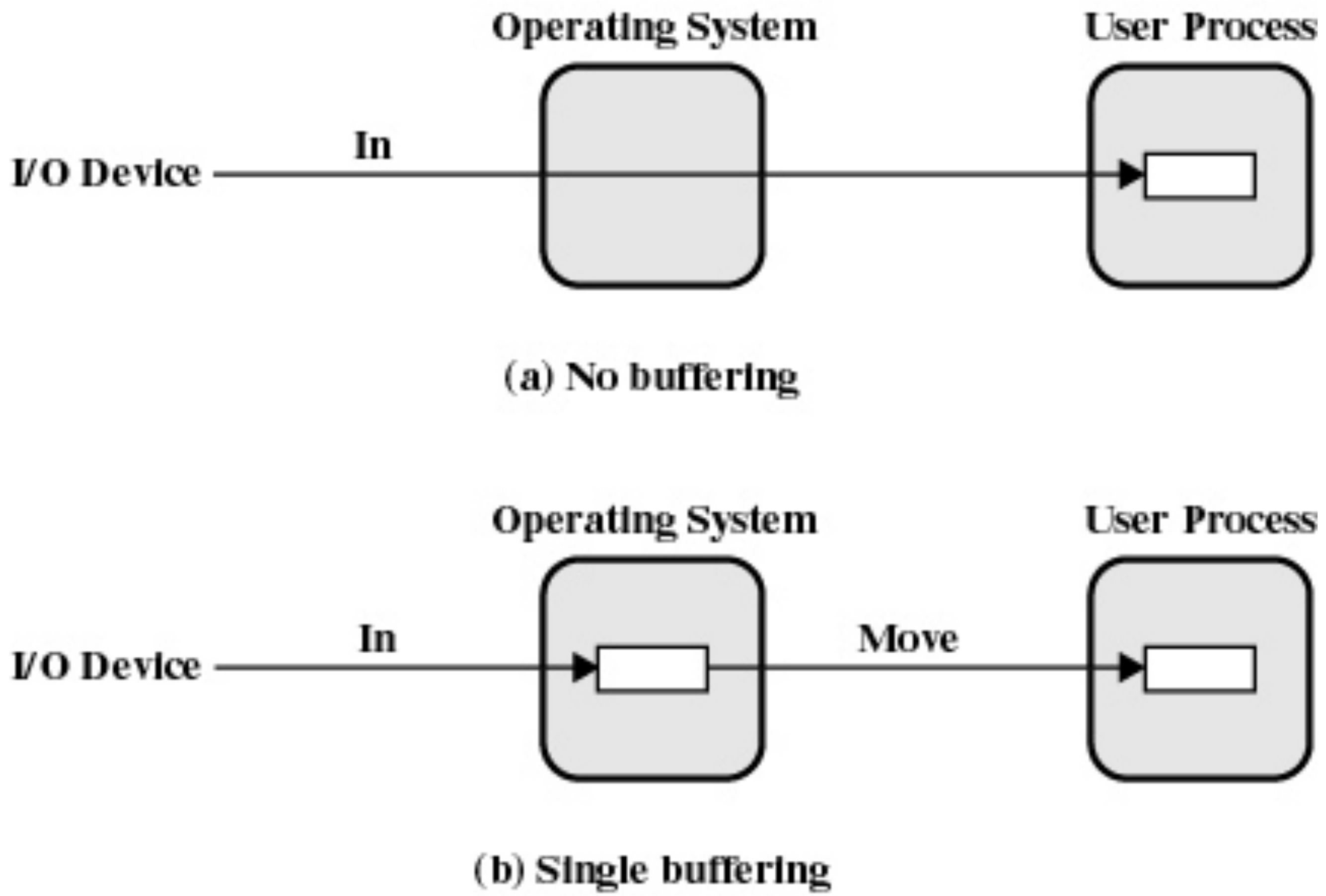


Figure 11.6 I/O Buffering Schemes (input)

Single Buffer

- **Block-oriented**
  - User process can process one block of data while next block is read in
  - Swapping can occur since input is taking place in system memory, not user memory
  - Operating system keeps track of assignment of system buffers to user processes

Single Buffer

- **Stream-oriented**
  - Used a line at time
  - User input from a terminal is one line at a time with carriage return signaling the end of the line
  - Output to the terminal is one line at a time

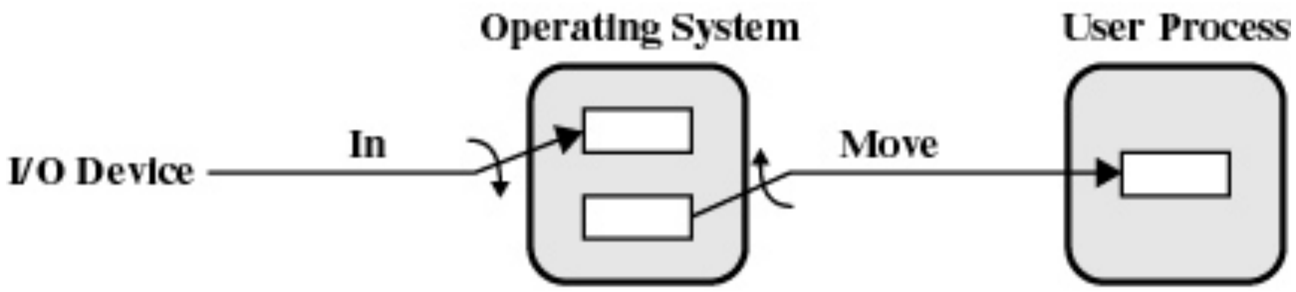
Double Buffer

- **Use two system buffers instead of one**
- **A process can transfer data to or from one buffer while the operating system empties or fills the other buffer**

Circular Buffer

- More than two buffers are used
- Each individual buffer is one unit in a circular buffer
- Used when I/O operation must keep up with process

I/O Buffering



(c) Double buffering

(d) Circular buffering

Summary

- **We have covered**
  - **Different types of I/O devices**
  - **How DMA works and various DMA organisations**
  - **Why data is buffered and various buffering schemes**

Next Lecture

- **We will talk about random access devices**
- **Lecture Notes: http://www.cs.rhul.ac.uk/~karl**