

# Computer System Overview

## Chapter 1

# Operating System

- Exploits the hardware resources of one or more processors
- Provides a set of services to system users
- Manages secondary memory and I/O devices

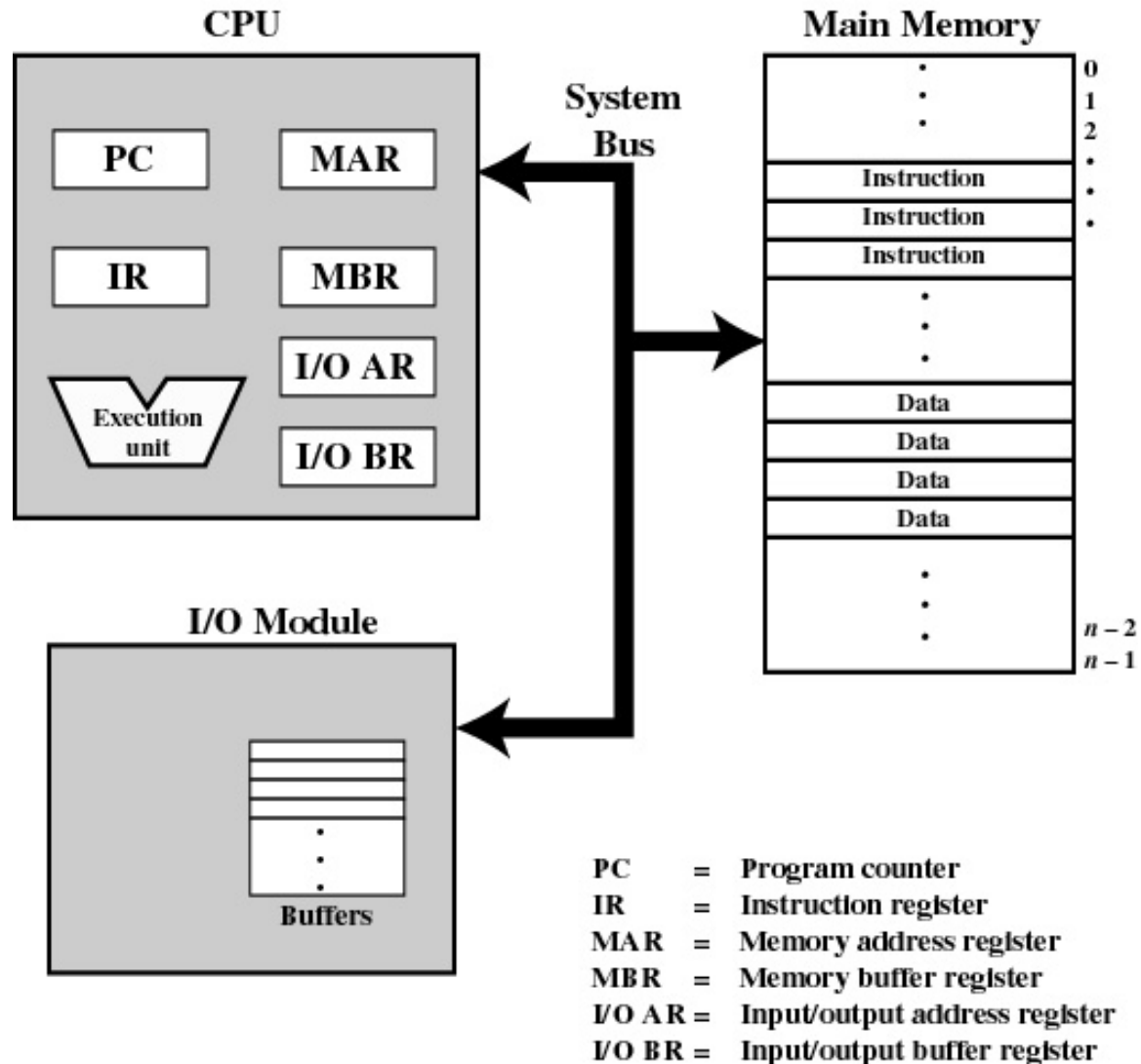


# Basic Elements

- Processor
- Main Memory
  - referred to as real memory or primary memory
  - volatile
- I/O modules
  - secondary memory devices
  - communications equipment
  - terminals
- System bus
  - communication among processors, memory, and I/O modules



# Top-Level Components



# Processor Registers

- *User-visible registers*
  - Enable programmer to minimize main-memory references by optimizing register use
- *Control and status registers*
  - Used by processor to control operating of the processor
  - Used by operating-system routines to control the execution of programs



# User-Visible Registers

- May be referenced by machine language
- Available to all programs - application programs and system programs
- Types of registers
  - Data
  - Address
    - Index
    - Segment pointer
    - Stack pointer



# User-Visible Registers

- Address Registers
  - Index
    - involves adding an index to a base value to get an address
  - Segment pointer
    - when memory is divided into segments, memory is referenced by a segment and an offset
  - Stack pointer
    - points to top of stack



# Control and Status Registers

- Program Counter (PC)
  - Contains the address of an instruction to be fetched
- Instruction Register (IR)
  - Contains the instruction most recently fetched
- Program Status Word (PSW)
  - condition codes
  - Interrupt enable/disable
  - Supervisor/user mode





# Control and Status Registers

- Condition Codes or Flags
  - Bits set by the processor hardware as a result of operations
  - Can be accessed by a program but not altered
  - Examples
    - positive result
    - negative result
    - zero
    - Overflow



# Instruction Cycle



# Instruction Fetch and Execute

- The processor fetches the instruction from memory
- Program counter (PC) holds address of the instruction to be fetched next
- Program counter is incremented after each fetch



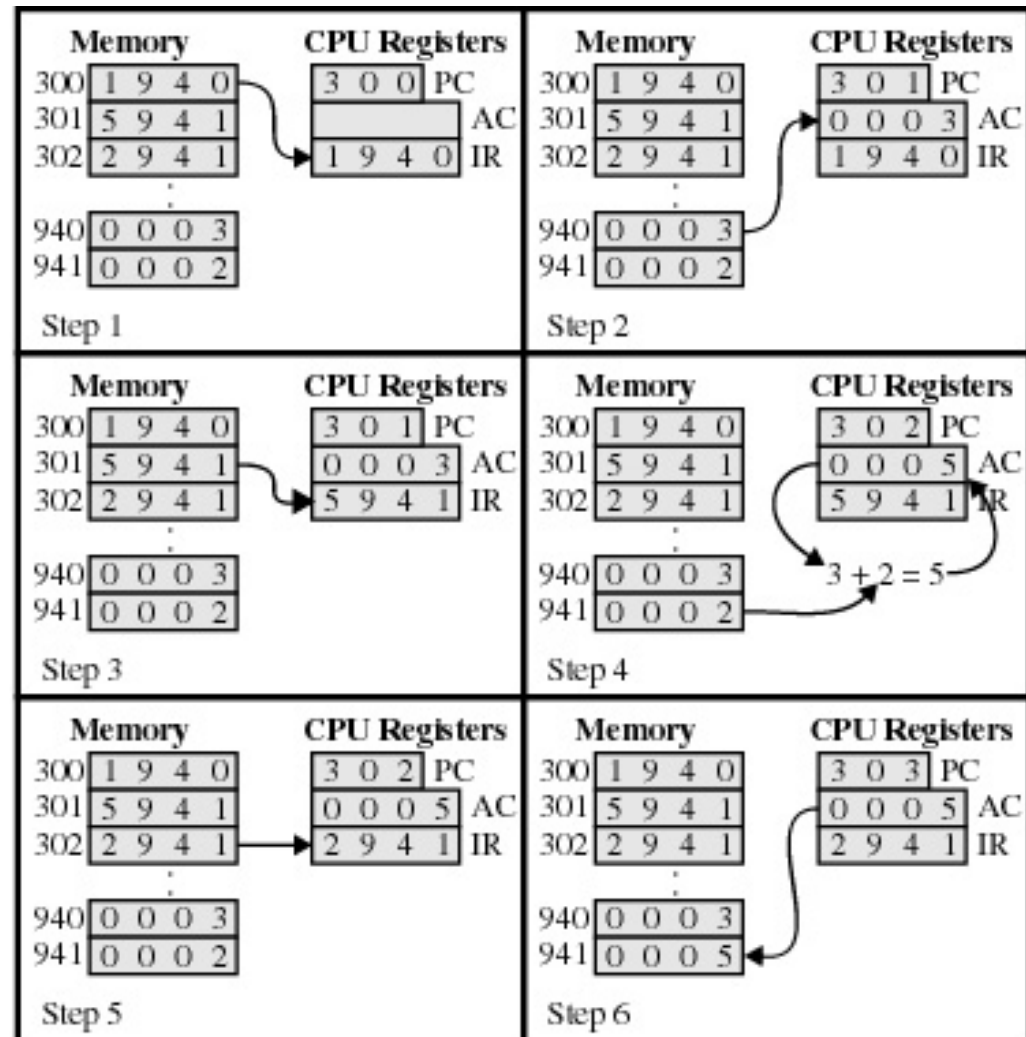
# Instruction Register

- Fetched instruction is placed in the instruction register
- Types of instructions
  - Processor-memory
    - transfer data between processor and memory
  - Processor-I/O
    - data transferred to or from a peripheral device
  - Data processing
    - arithmetic or logic operation on data
  - Control
    - alter sequence of execution



# Example of Program Execution

The fragment adds the contents of a word at address 940 to the contents of word at address 941 where it will store the result as well.



# Direct Memory Access (DMA)

- I/O exchanges occur directly with memory
- Processor grants I/O module authority to read from or write to memory
- Relieves the processor responsibility for the exchange
- Processor is free to do other things



# Interrupts

- An interruption of the normal sequence of execution
- Improves processing efficiency
- Allows the processor to execute other instructions while an I/O operation is in progress
- A suspension of a process caused by an event external to that process and performed in such a way that the process can be resumed





# Classes of Interrupts

- ***Program***
  - arithmetic overflow
  - division by zero
  - execute illegal instruction
  - reference outside user's memory space
- ***Timer***
- ***I/O***
- ***Hardware failure***



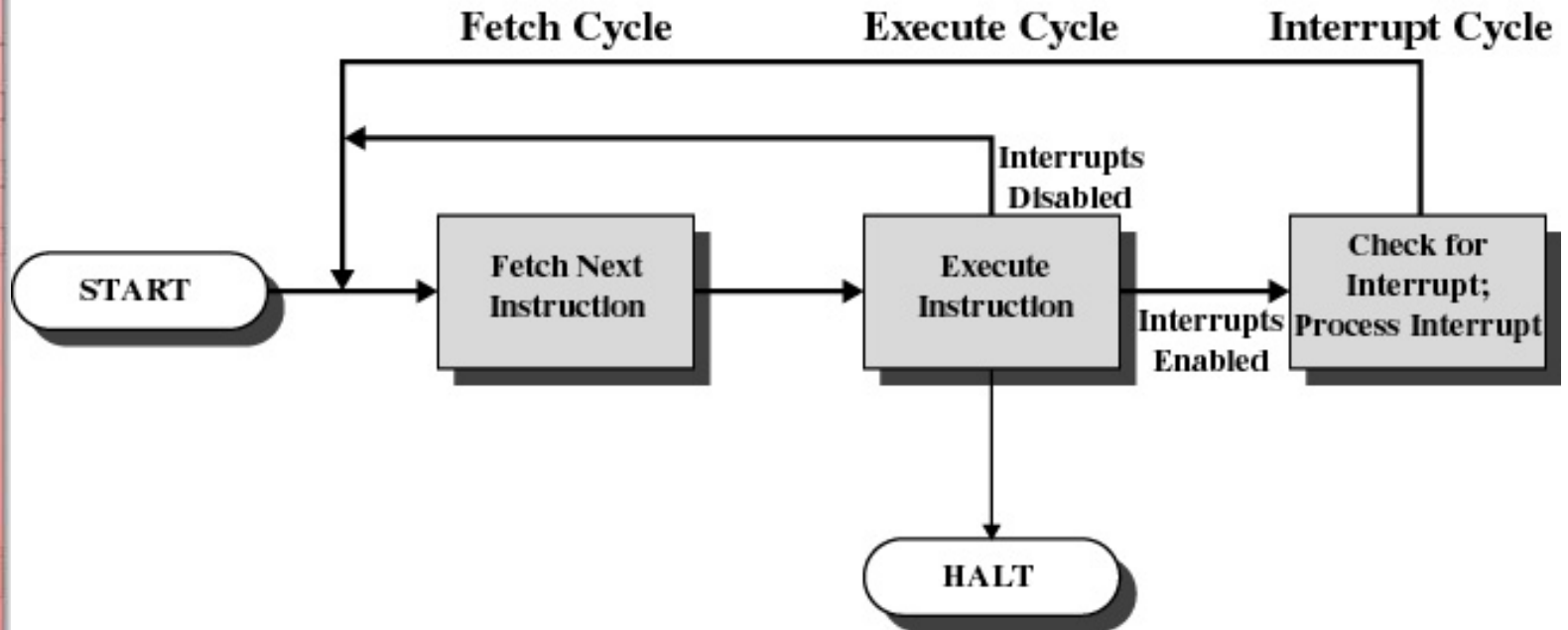


# Interrupt Handler

- A program that determines nature of the interrupt and performs whatever actions are needed
- Control is transferred to this program
- Generally part of the operating system



# Interrupt Cycle

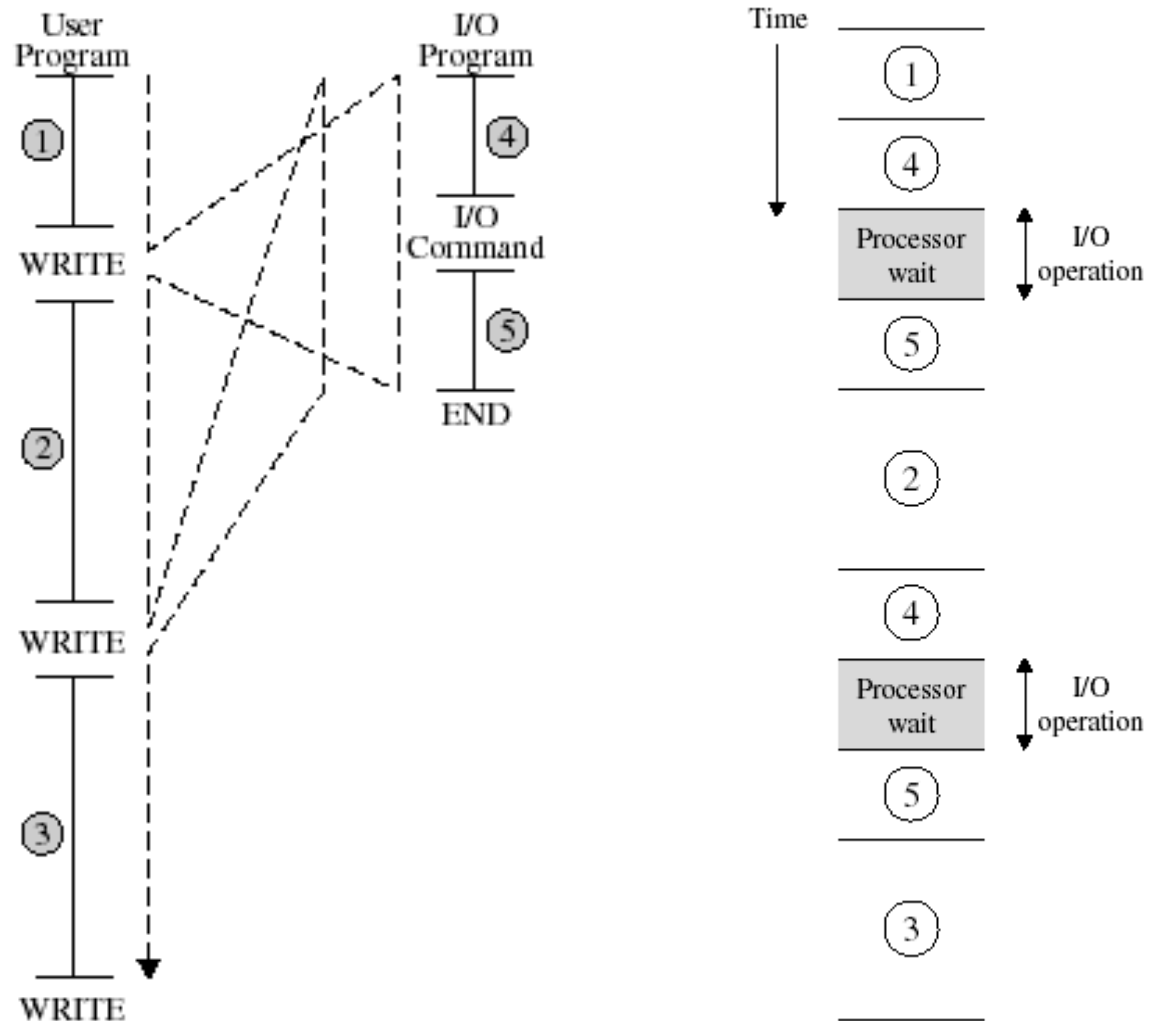


# Interrupt Cycle

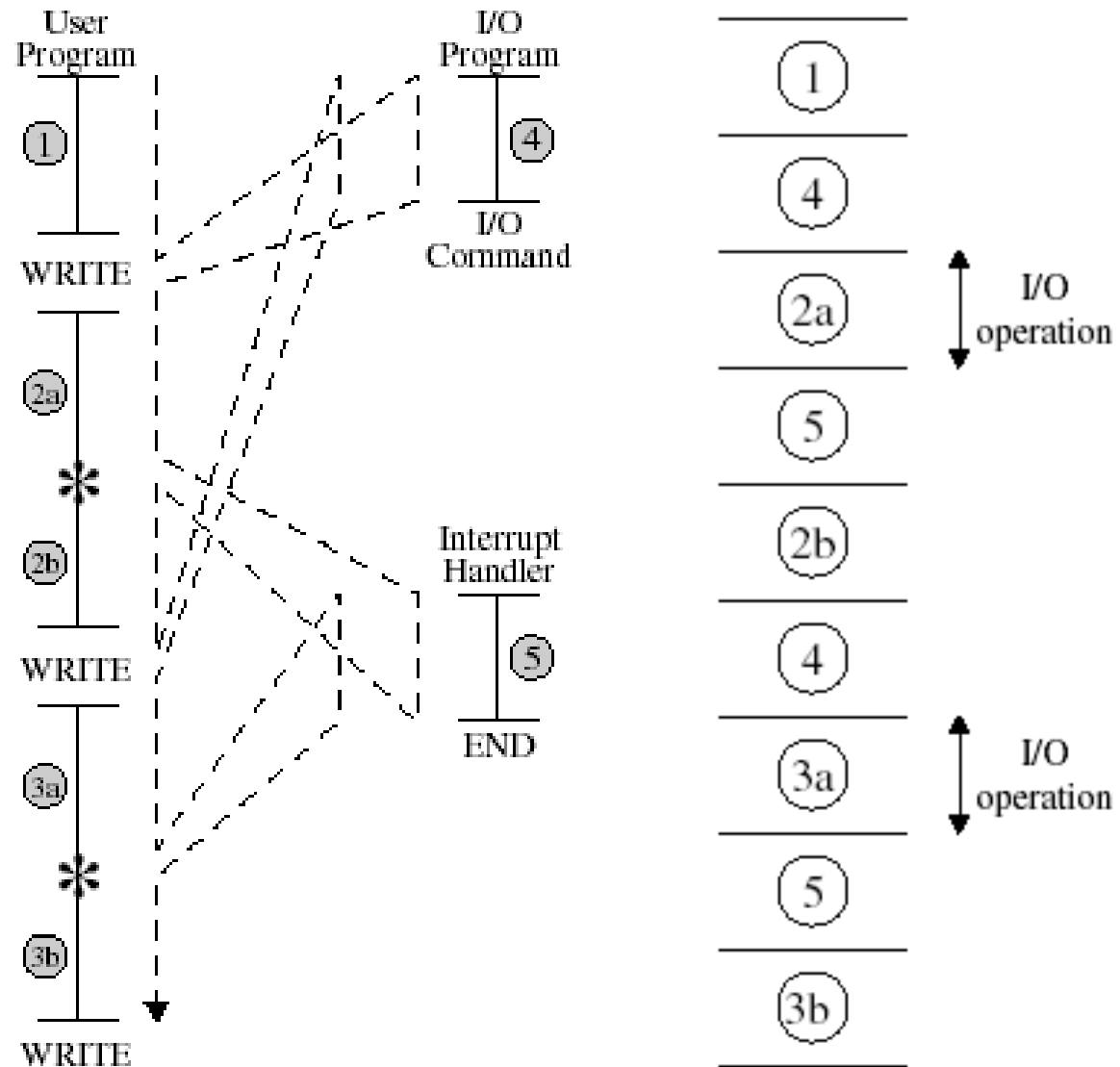
- Processor checks for interrupts
- If no interrupts fetch the next instruction for the current program
- If an interrupt is pending, suspend execution of the current program, and execute the interrupt handler



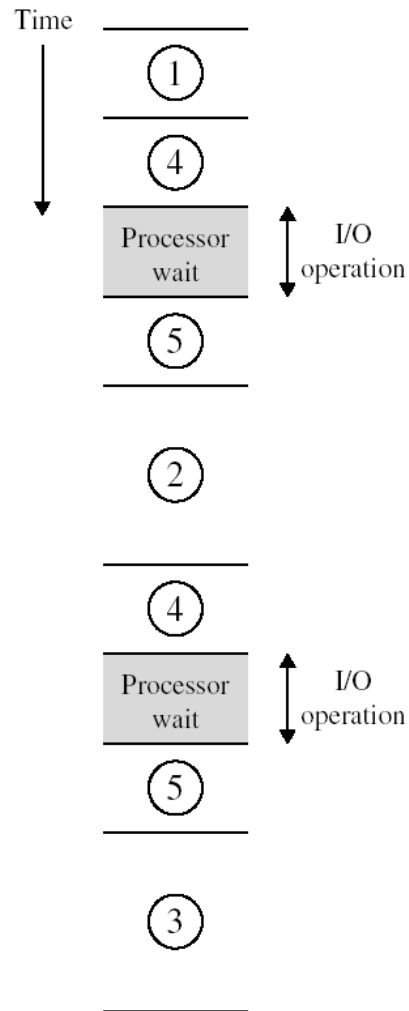
# Program Flow of Control Without Interrupts



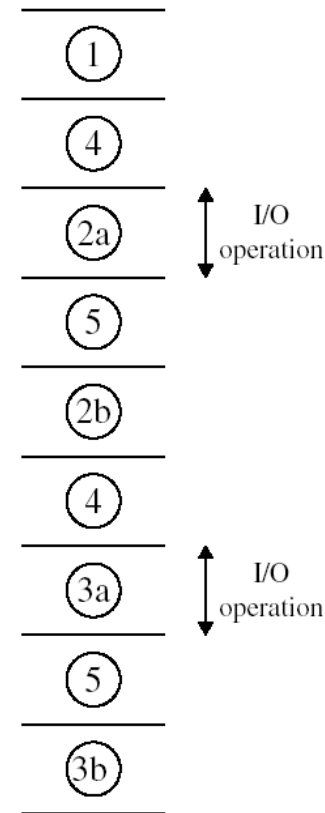
# Program Flow of Control With Interrupts



# Interrupt Processing

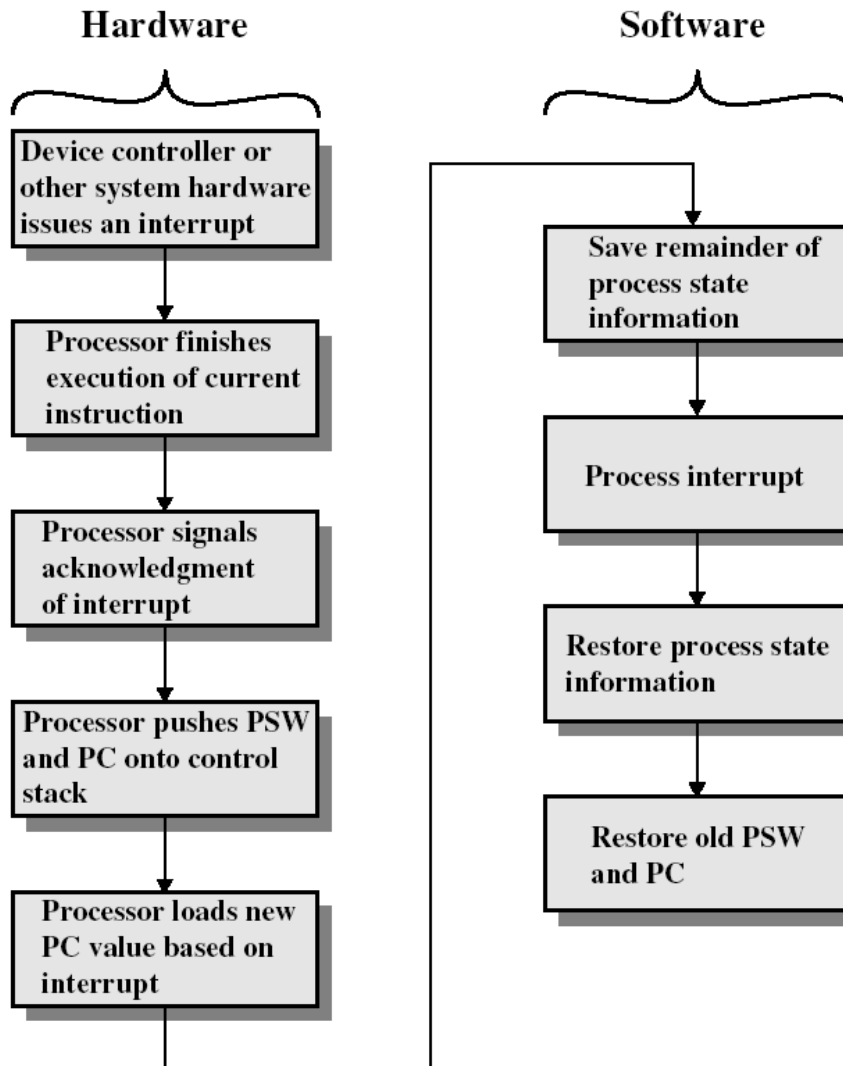


(a) Without interrupts



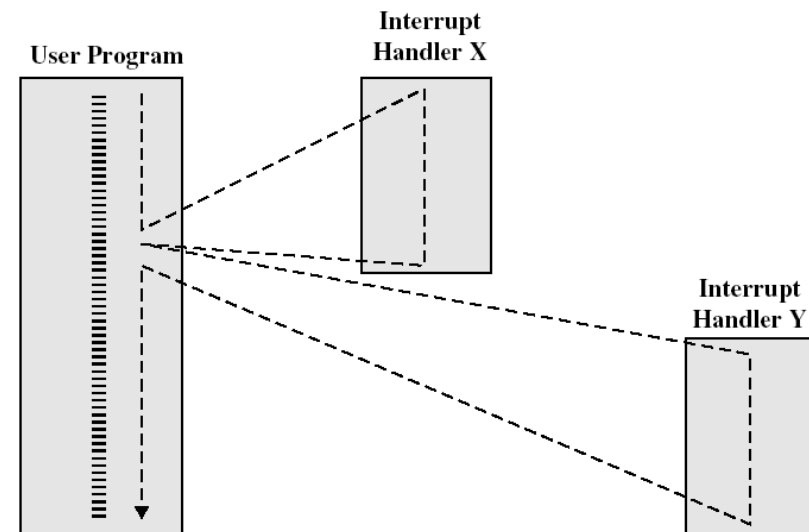
(b) With interrupts

# Interrupt Processing



# Multiple Interrupts

- Disable interrupts while an interrupt is being processed
  - Processor ignores any new interrupt request signals



(a) Sequential interrupt processing





# Multiple Interrupts Sequential Order

- Disable interrupts so processor can complete task
- Interrupts remain pending until the processor enables interrupts
- After interrupt handler routine completes, the processor checks for additional interrupts

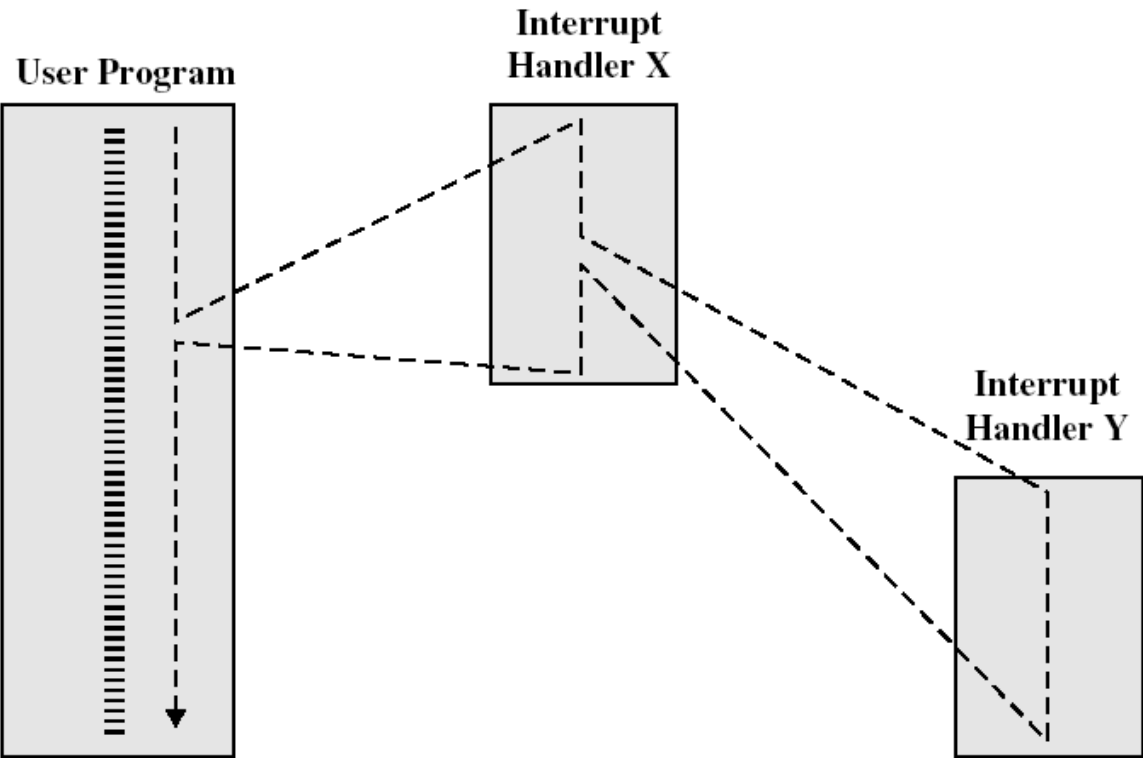


# Multiple Interrupts Priorities

- Higher priority interrupts cause lower-priority interrupts to wait
- Causes a lower-priority interrupt handler to be interrupted
- Example when input arrives from communication line, it needs to be absorbed quickly to make room for more input



# Multiple Interrupts Priorities



### (b) Nested interrupt processing

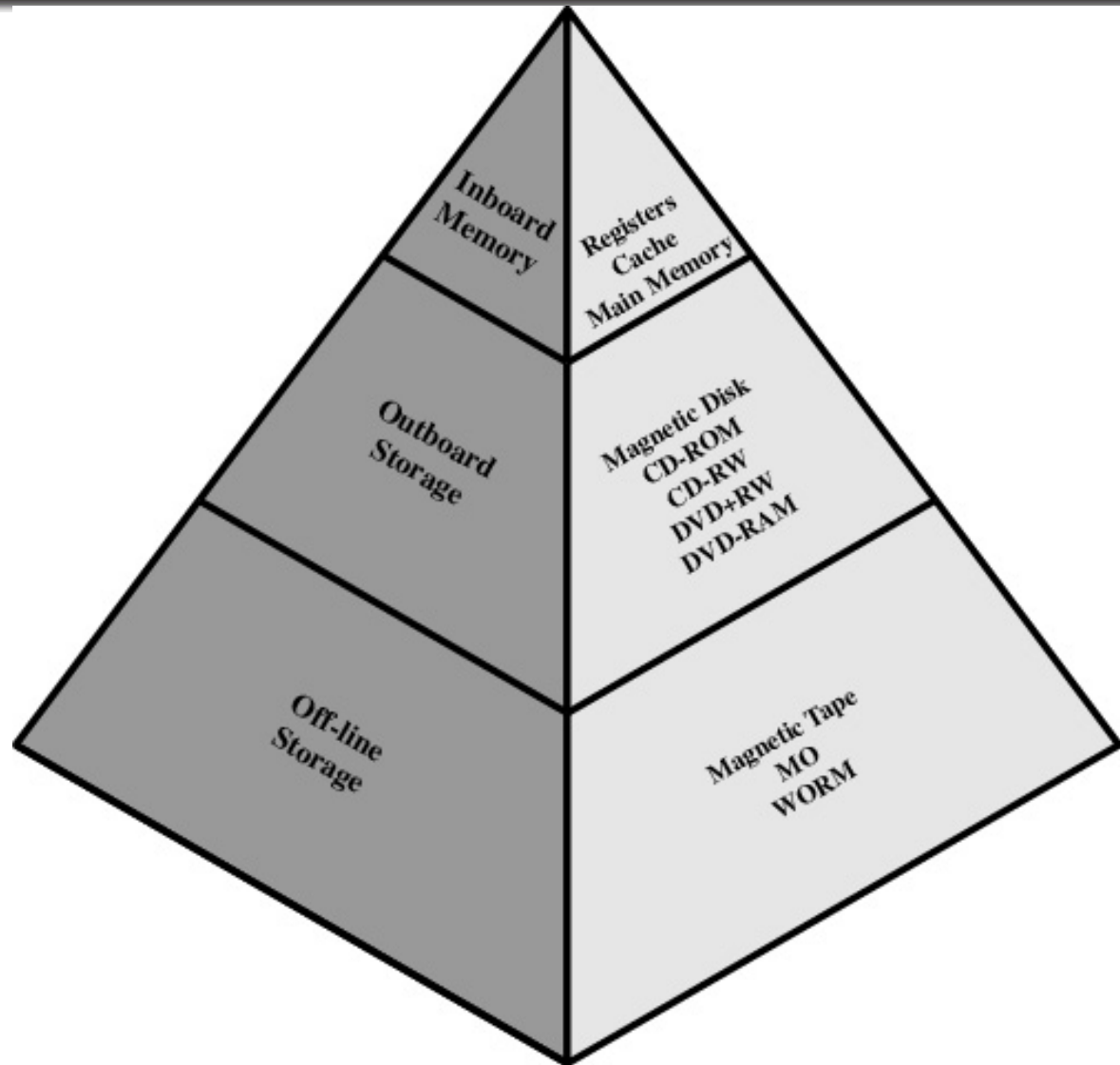


# Multiprogramming

- Processor has more than one program to execute
- The sequence the programs are executed depend on their relative priority and whether they are waiting for I/O
- After an interrupt handler completes, control may not return to the program that was executing at the time of the interrupt

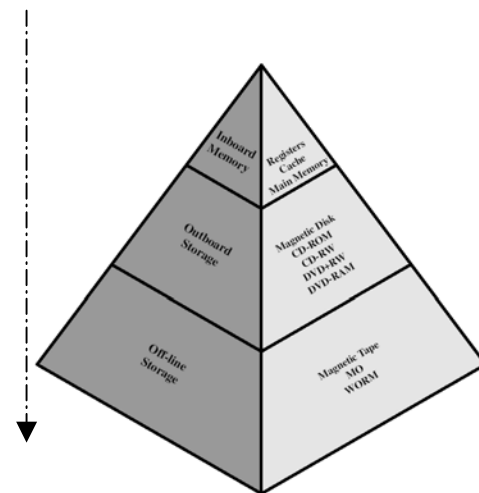


# Memory Hierarchy



# Going Down the Hierarchy

- Decreasing cost per bit
- Increasing capacity
- Increasing access time
- Decreasing frequency of access of the memory by the processor
  - *locality of reference*



# Disk Cache

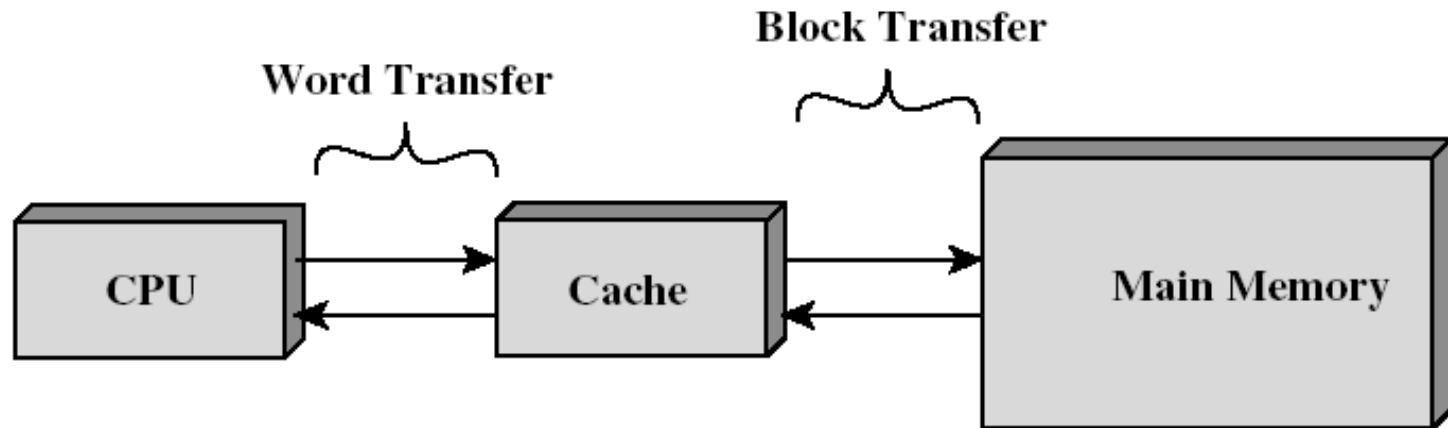
- A portion of main memory used as a buffer to temporarily to hold data for the disk
- Disk writes are *clustered*
- Some data written out may be referenced again. The data are retrieved rapidly from the software cache instead of slowly from disk





# Cache Memory

- Processor speed is faster than memory speed
- Increase the speed of accessing memory
- Invisible to operating system

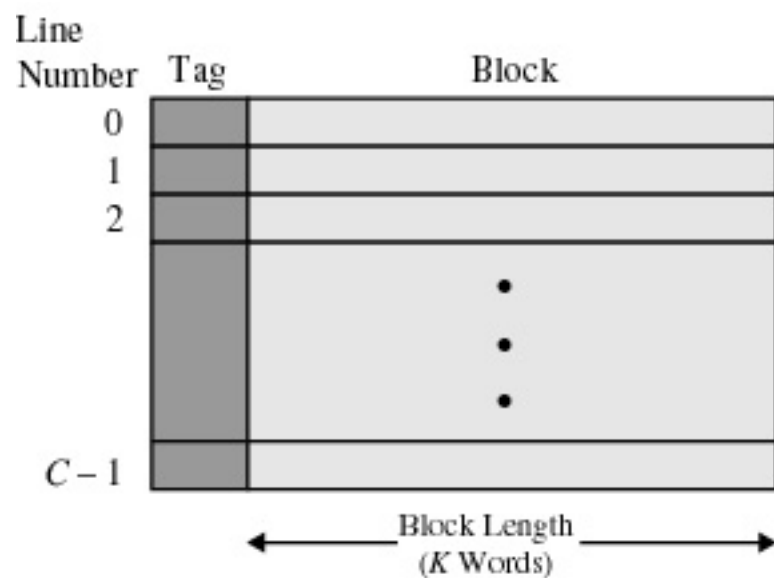




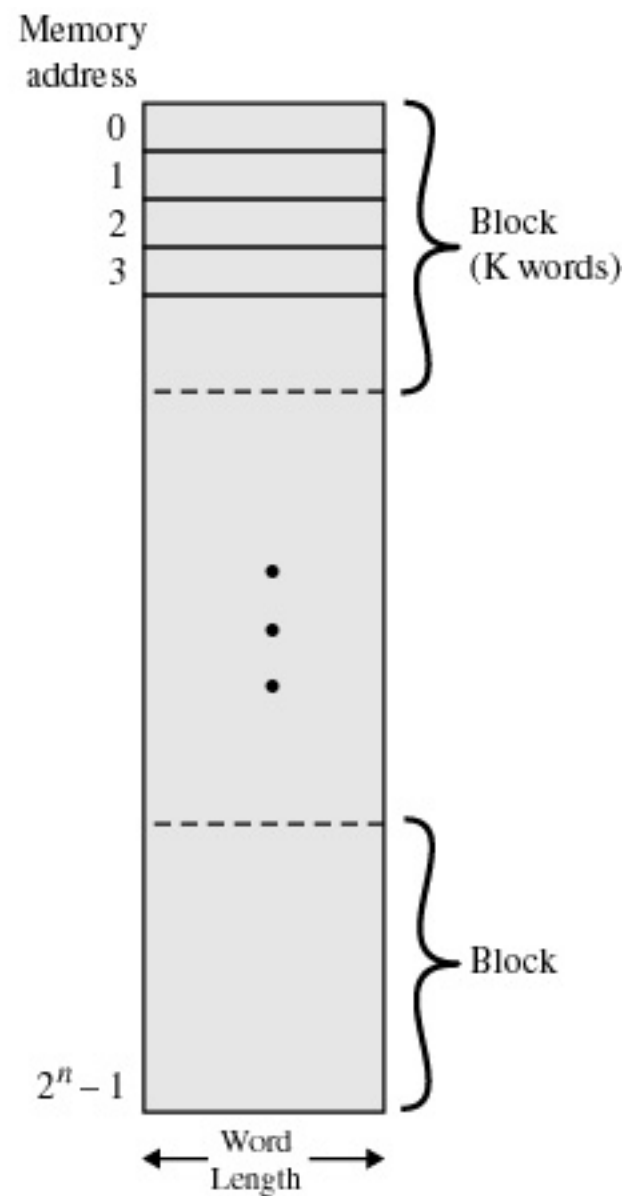
# Cache Memory

- Contains a portion of main memory
- Processor first checks cache
- If not found in cache, the block of memory containing the needed information is moved to the cache





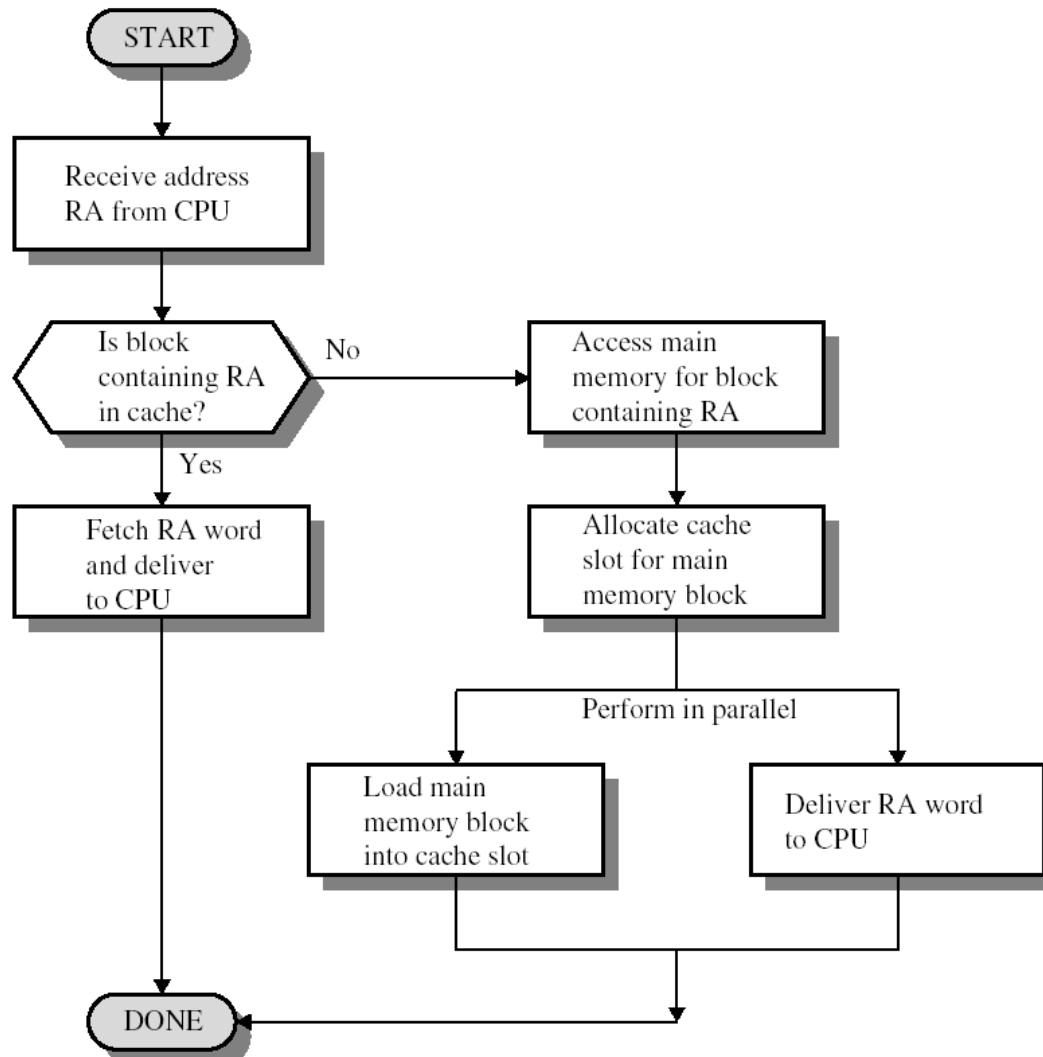
(a) Cache



(b) Main memory

**Figure 1.17 Cache/Main-Memory Structure**

# Read Operations



# Cache Design: key elements

- ***Cache size***
  - small caches have a significant impact on performance
- ***Block size***
  - the unit of data exchanged between cache and main memory
  - hit means the information was found in the cache
  - larger block size more hits until probability of using newly fetched data becomes less than the probability of reusing data that has been moved out of cache



# Cache Design: key elements

- ***Mapping function***
  - determines which cache location the block will occupy
- ***Replacement algorithm***
  - determines which block to replace
  - Least-Recently-Used (LRU) algorithm



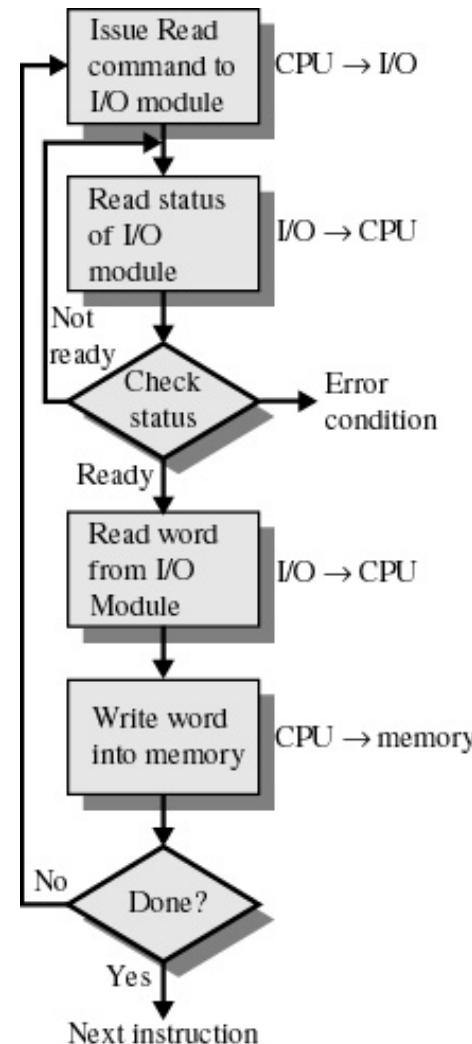
# Cache Design: key elements

- *Write policy*
  - When the memory write operation takes place
  - Can occur every time block is updated
  - Can occur only when block is replaced
    - Minimizes memory operations
    - Leaves memory in an obsolete state



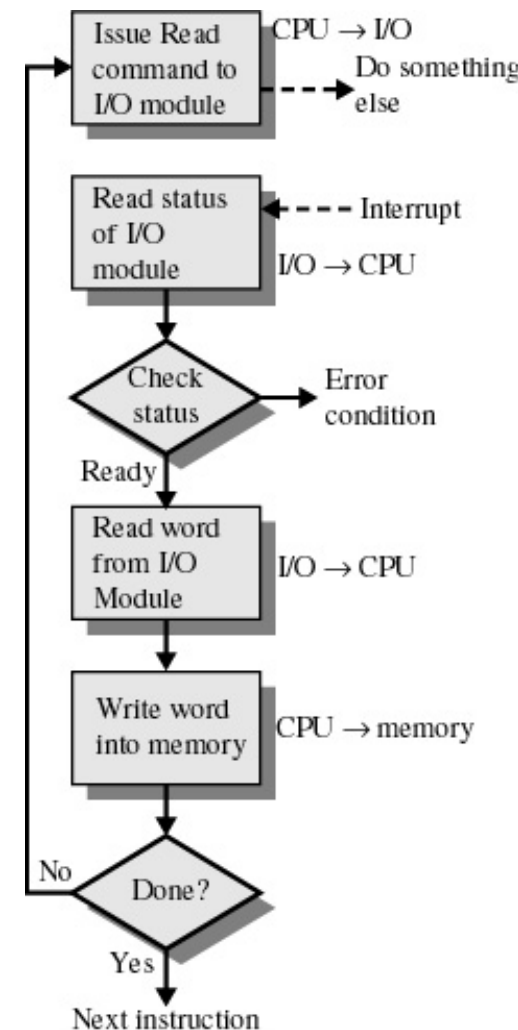
# Programmed I/O

- I/O module performs the action, not the processor
- Sets appropriate bits in the I/O status register
- No interrupts occur
- Processor checks status until operation is complete



# Interrupt-Driven I/O

- Processor is interrupted when I/O module ready to exchange data
- Processor is free to do other work
- No needless waiting
- Consumes a lot of processor time because every word read or written passes through the processor





# Direct Memory Access

- Transfers a block of data directly to or from memory
- An interrupt is sent when the task is complete
- The processor is only involved at the beginning and end of the transfer

