Computer Architecture and Organization

Input/Output Organization

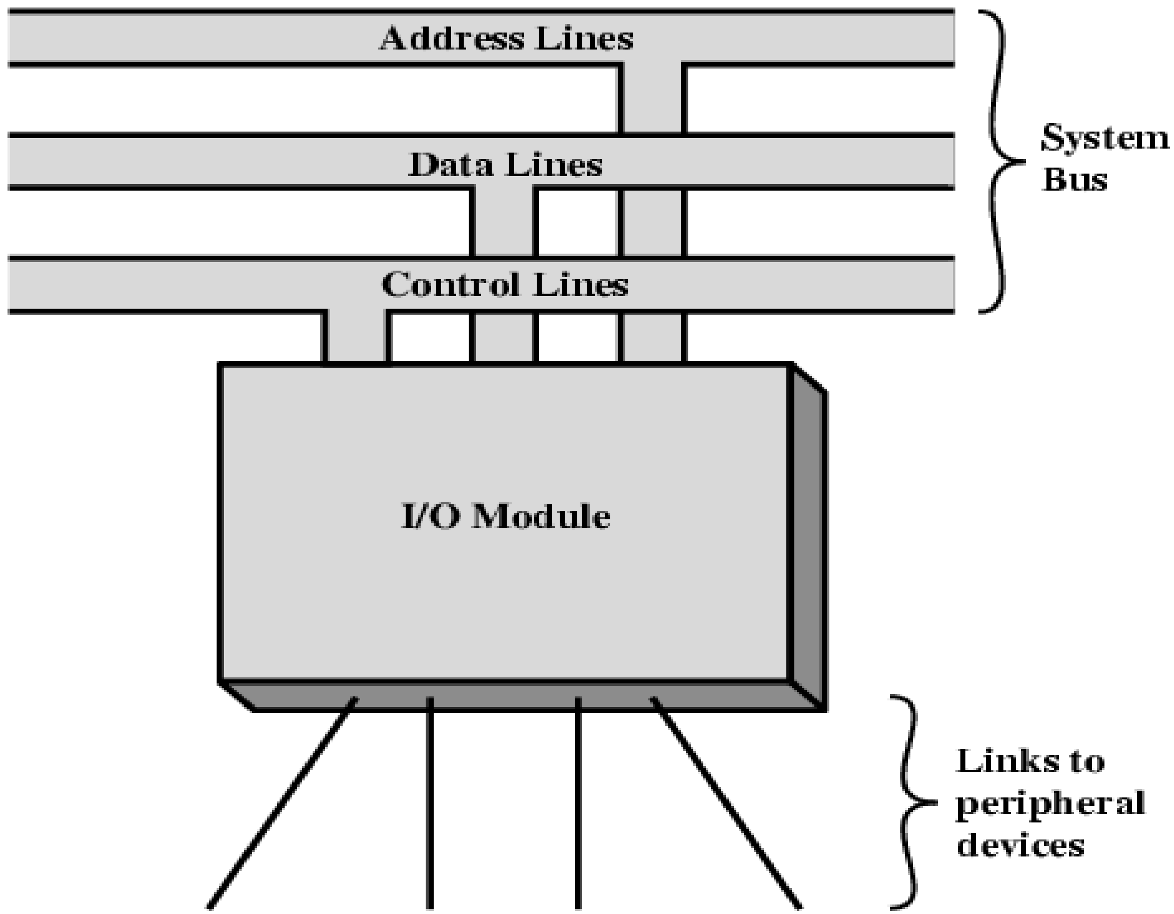
Input/Output Problems

- Input / Output modules are the third critical element of the computer system (others are the CPU and the memory)
- All computer systems must have efficient means to receive input and deliver output
- Wide variety of peripherals (external devices)
  - Delivering different amounts of data
  - At different speeds
  - In different formats
- All slower than CPU and RAM
- Need I/O modules

Input/Output Module

- External devices are not generally connected directly into the bus structure of the computer
- I/O module is an interface for the external devices (peripherals) to CPU and Memory

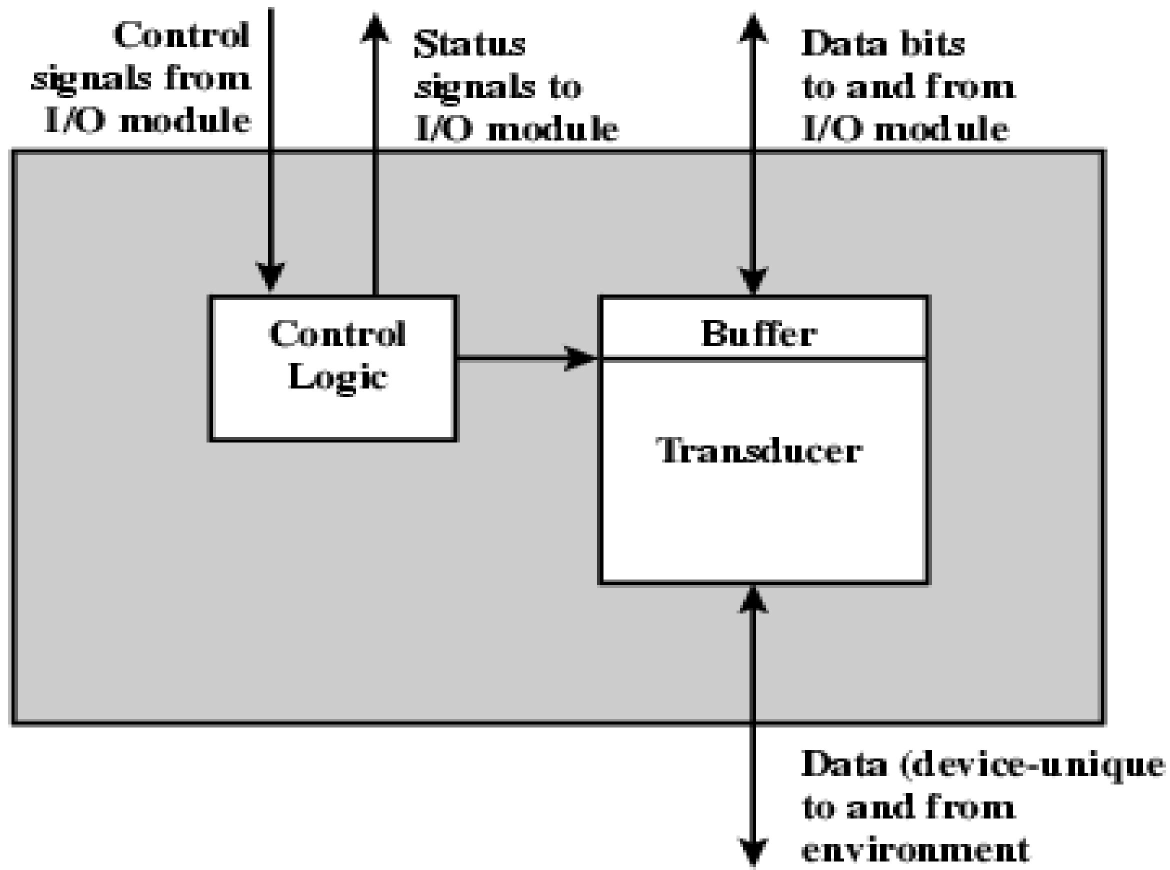
Generic Model of I/O Module



External Devices

- Exchanging data between the external environment and the computer.
- Also known as peripheral devices which connected to an I/O module.
- Can be classify into three categories:
- Human readable - for communicating with the computer user.
  - Screen, printer, keyboard
- Machine readable - for communicating with equipment.
  - Magnetic disk,tape system
- Communication - for communicating with remote devices.
  - Modem, Network Interface Card (NIC)

External Device Block Diagram



External Device Interface

- The interface to the I/O module is in the form of control, data and status signal.
- Control signal determine the function that the device will perform (e.g: READ,WRITE).
- Data are in the form of a set of bits to be sent to or received from the I/O module.
- Status signals indicates the state of the device (READY,NOT-READY).
- Control logic associated with the device, control the device operation in response to direction from the I/O.
- The transducer converts data from electrical to other form of energy during output and from other forms to electrical during input.

KEYBOARD / MONITOR

- The most common of means of computer/user interaction is a keyboard/monitor arrangement.
- This input is then transmitted to the computer and may also be displayed on the monitor.
- In addition ,the monitor display data provided by the computer.
- The basic unit of exchange is the character.
- Associated with each character is a code, typically 7 or 8 bits in length.
- International Reference Alphabet (IRA) is the most commonly used text code. Each character in this code is represented by a unique 7-bit binary code; thus 128 different character can be represented.
- IRA was formerly known as International Alphabet Number 5 (IA5). The U.S national version of IRA is referred to as the American Standard Code for Information Interchange (ASCII).

International Reference Alphabet (IRA)

Table 7.1 The International Reference Alphabet (IRA)

bit position

b_7				0	0	0	0	1	1	1	1
b_6				0	0	1	1	0	0	1	1
b_5				0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1								
0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	STX	DC2	"	2	B	R	b	r
0	0	1	1	ETX	DC3	#	3	C	S	c	s
0	1	0	0	EOT	DC4	$	4	D	T	d	t
0	1	0	1	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	ACK	SYN	&	6	F	V	f	v
0	1	1	1	BEL	ETB	'	7	G	W	g	w
1	0	0	0	BS	CAN	(	8	H	X	h	x
1	0	0	1	HT	EM	)	9	I	Y	i	y
1	0	1	0	LF	SUB	*	:	J	Z	j	z
1	0	1	1	VT	ESC	+	;	K	[	k	{
1	1	0	0	FF	FS	,	<	L	\	l	|
1	1	0	1	CR	GS	-	=	M	]	m	}
1	1	1	0	SO	RS	.	>	N	^	n	~
1	1	1	1	SI	US	/	?	O	_	o	DEL

- In the table, the bits of each character are labeled from b_7 (Most significant bit) to b_1 (Least significant bit)
- Example: The character “K” is $b_7b_6b_5b_4b_3b_2b_1 = 1001011$
- Characters are two types:printable and control.
- Printable characters are the alphabetic, numeric and special character that can be printed on paper or displayed on a screen.
- Control characters control some operation in the computer.

I/O Module Function

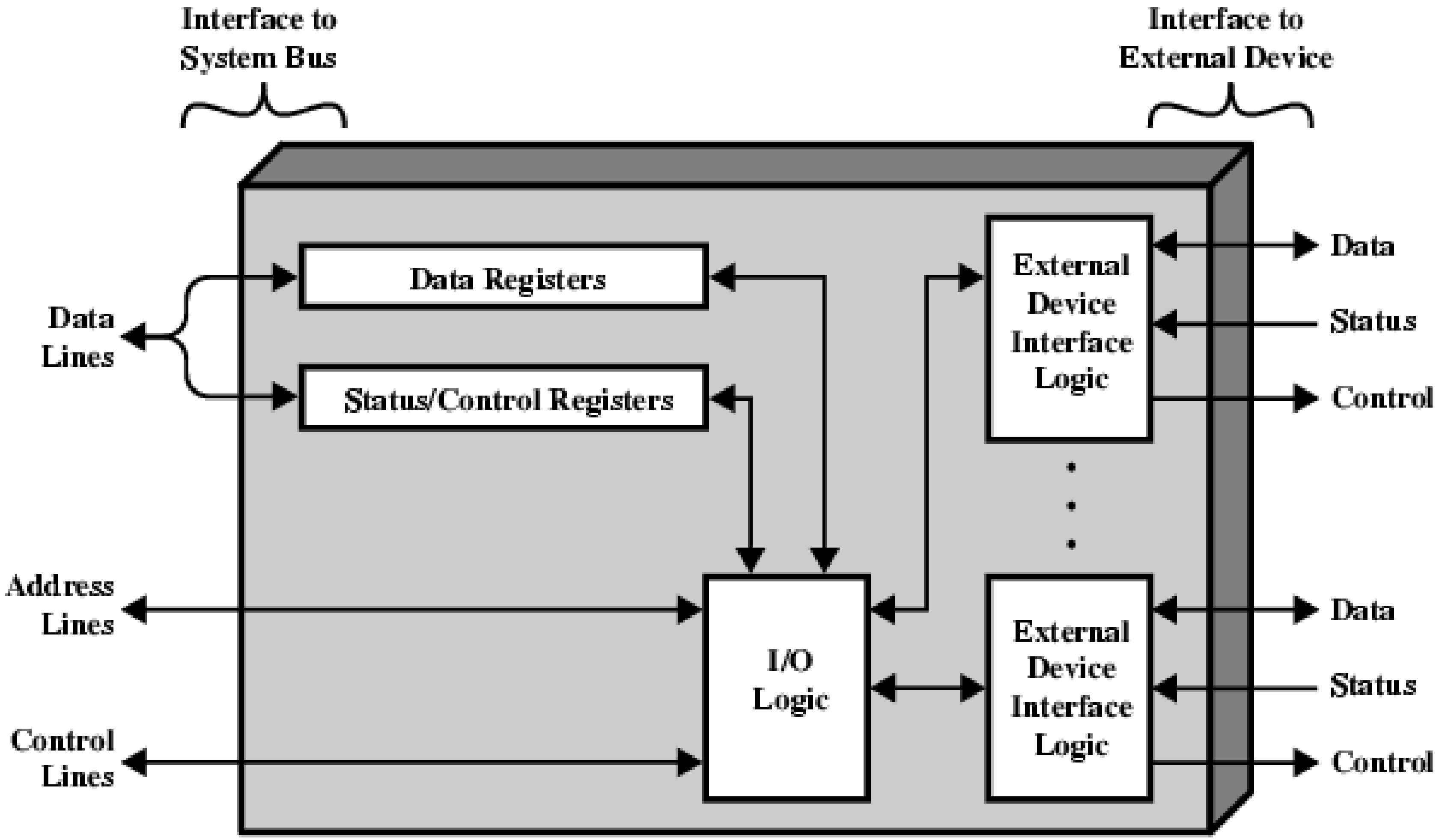
The major function for an I/O module:

- Control & Timing-To coordinate the flow of traffic between internal resources (main memory, system bus) and external resources.
- CPU Communication-communicate with processor in term of accept commands from processor,exchanged data,status reporting and address recognition.
- Device Communication -communicate with external devices
- Data Buffering-Temporarily hold data between being transferred between the I/O module and external devices
- Error Detection-detect errors and report errors to the processor

I/O Steps

- CPU checks I/O module device status
- I/O module returns status
- If ready, CPU requests data transfer
- I/O module gets data from device
- I/O module transfers data to CPU

I/O Module Structure Diagram



I/O Module Structure

-The module connects to the rest of the computer through a set of system bus lines.

-Data transferred to and from the module are buffered in one or more data register.

-One or more status register provide current status information.

-A status register may also function as a control register, to accept detailed control information from the processor.

-The logic within the module the module interacts with the processor via a set of control lines.

-The processor uses the control lines to issue commands to the I/O module.

-Some of the control lines may be used by the I/O module (for arbitration and status signal)

-Each I/O module has a unique address or a unique set of addresses if it controls more than one external device.

Input Output Techniques

There are three principle I/O technique:

- Programmed I/O
- Interrupt driven
- Direct Memory Access (DMA)

Programmed I/O

- CPU has direct control over I/O
  - Sensing status
  - Read/write commands
  - Transferring data
- CPU waits for I/O module to complete operation
- Wastes CPU time

Programmed I/O - Detail

- I/O occurs under the direct and continuous control of the program requesting the I/O operation.
- Data are exchange between the processor and the I/O module.
- The processor executes a program that gives it direct control of the I/O operation, including sensing device status, sending a read or write command and transferring the data.
- CPU waits until the I/O operation is completed before it can perform other tasks
- Completion indicated by a change in the module status bits
- CPU must periodically poll the module to check its status

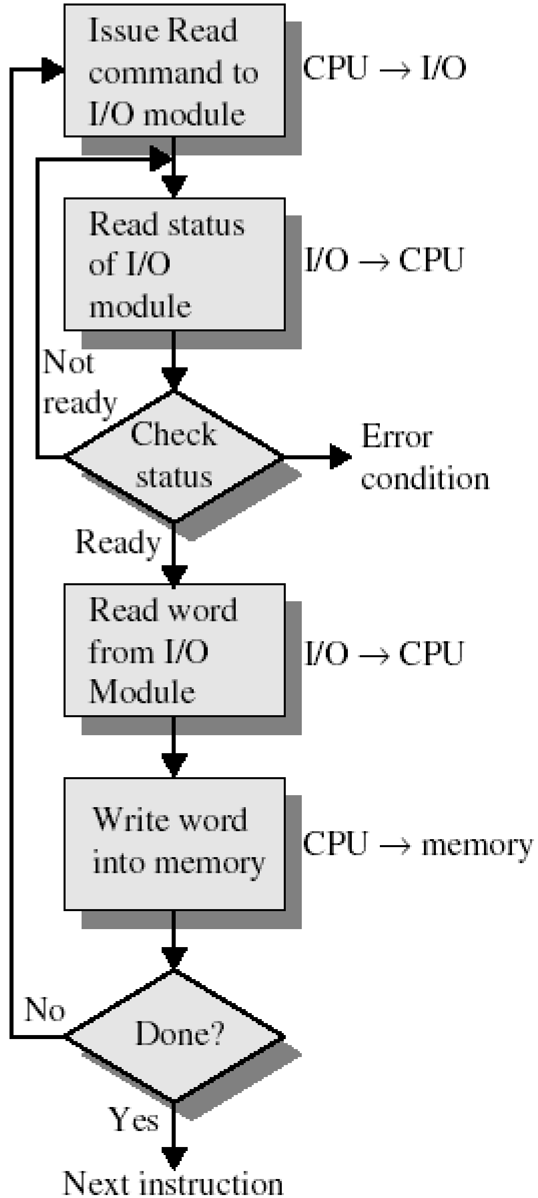
I/O Commands

- **Control**: Used to active a peripheral and tell it what to do. For example, a magnetic-tape unit may be instructed to rewind or to move forward one record. These commands are tailored to the particular type of peripheral device.

- **Test**: Used to test various status conditions associated with an I/O module and its peripherals. The processor will want to know that the peripheral of interest is powered on and available for use. It will also want to know if the most recent I/O operation is completed and if any errors occurred.

- **Read** : Causes the I/O module to obtain an item of data to peripheral and place it in an internal buffer. The processor can then obtain the data item by requesting that the I/O module place it on the data bus.

- **Write**: Causes the I/O module to take an item of data (byte or word) from the data bus and subsequently transmit that data item to the peripheral.



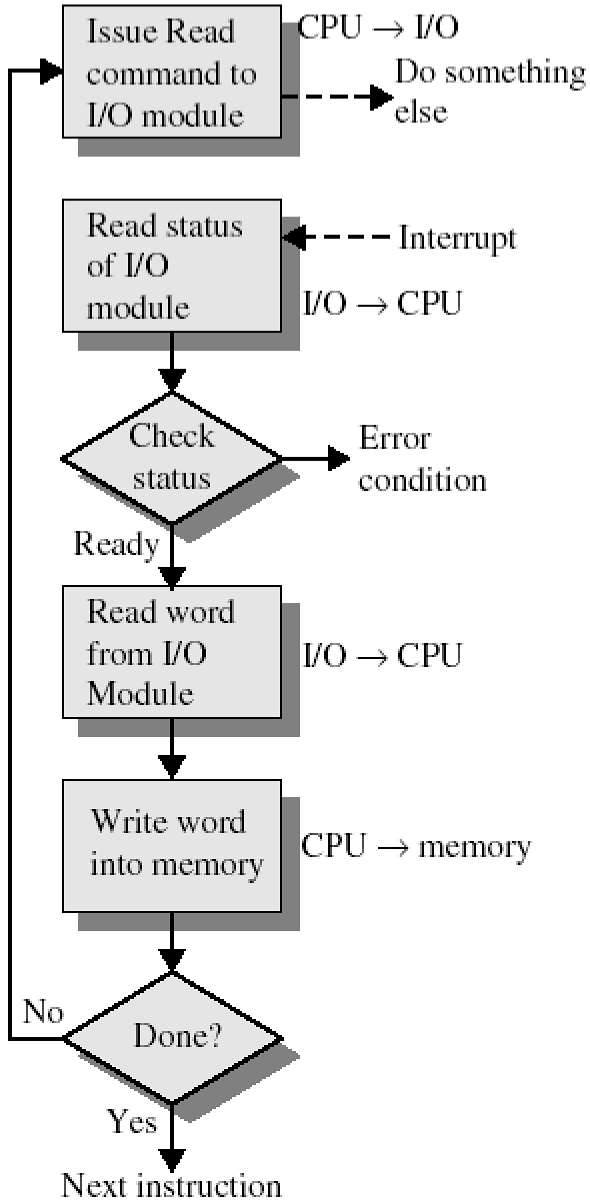
(a) Programmed I/O

Interrupt Driven I/O

- Overcomes CPU waiting
- No repeated CPU checking of device
- I/O module interrupts when ready

Interrupt Driven I/O
Basic Operation

- CPU issues read command
- I/O module gets data from peripheral whilst CPU does other work
- I/O module interrupts CPU
- CPU requests data
- I/O module transfers data



(b) Interrupt-driven I/O

CPU Viewpoint

- Issue read command
- Do other work
- Check for interrupt at end of each instruction cycle
- If interrupted:-
  - Save context (registers)
  - Process interrupt
    - Fetch data & store

Multiple Interrupts

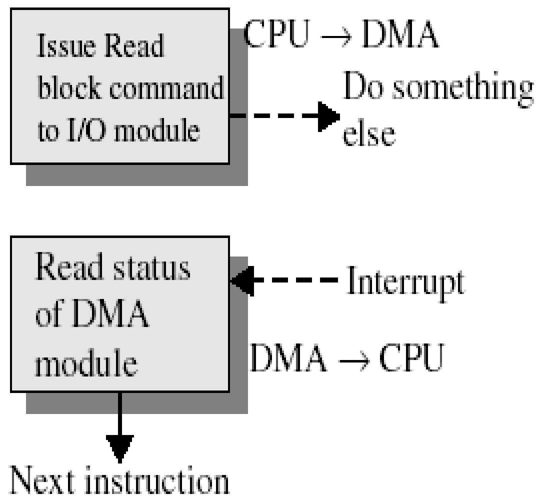
- Each interrupt line has a priority
- Higher priority lines can interrupt lower priority lines
- If bus mastering only current master can interrupt

Direct Memory Access (DMA)

- Interrupt driven and programmed I/O require active CPU intervention
  - Transfer rate is limited
  - CPU is tied up
- DMA is the answer
- A specialized I/O chip that takes over control of an I/O operation to move a large block of data.
- I/O module and main memory exchange data directly, without processor involvement.

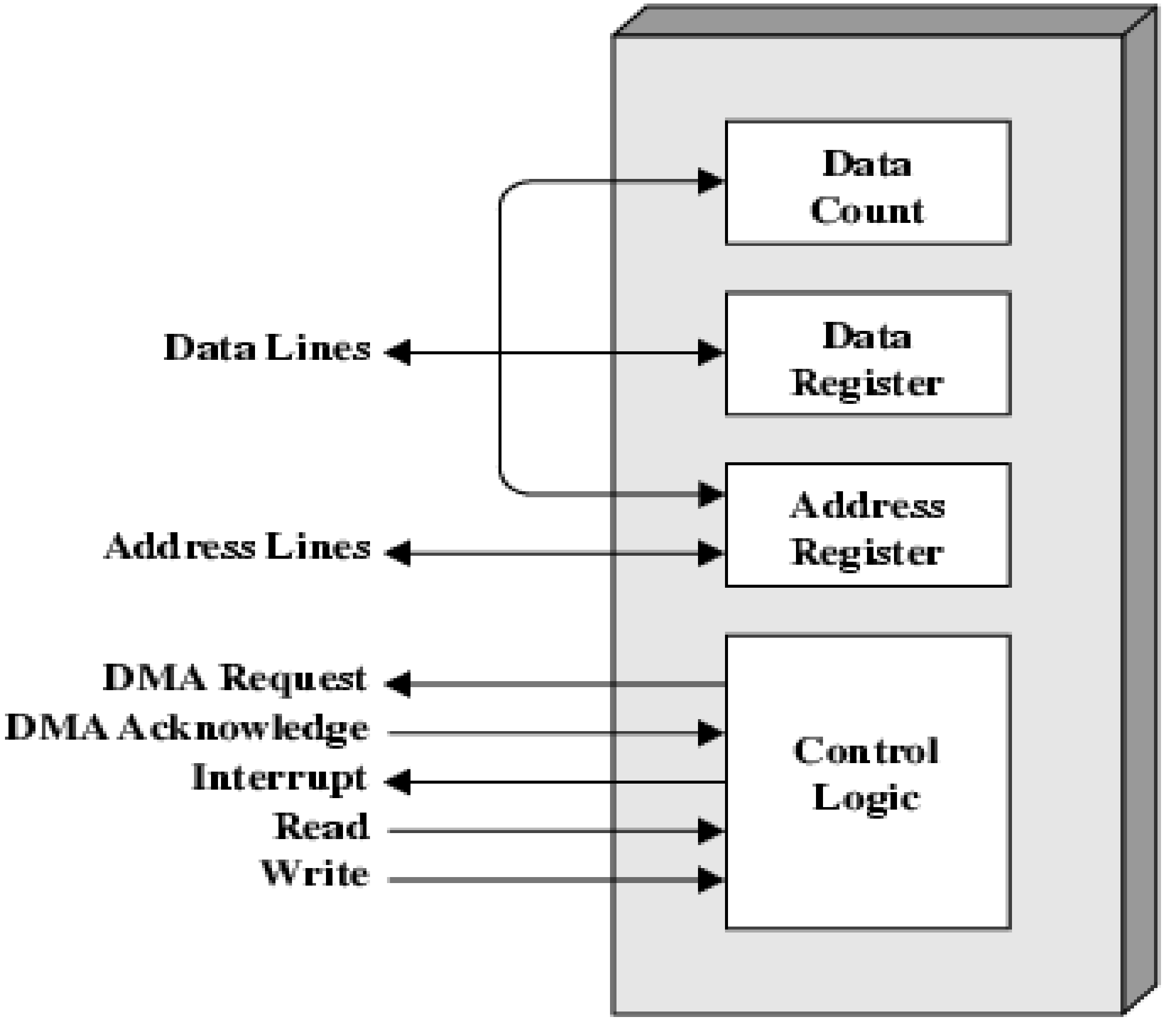
DMA Operation

- When the processor wishes to read or write a block of data, it issues a command to the DMA module by sending the following information:
  - Whether a read or write signal.
  - The address of the I/O device involved.
  - The starting location in memory to read or write to.
  - The number of word to be read or written.
- The processor then continues with other work (delegated this I/O operation to the DMA module)
- The DMA module transfer the entire block of data,one word at a time, directly to or from memory, without going through the processor
- When the transfer is complete, the DMA module sends a interrupt signal to the processor
- Thus, the processor is involved only at the beginning and end of the transfer

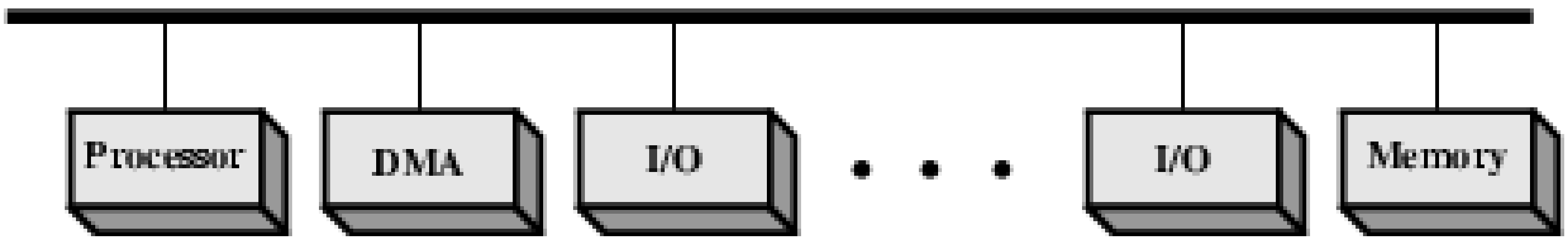


(c) Direct memory access

DMA Module Diagram

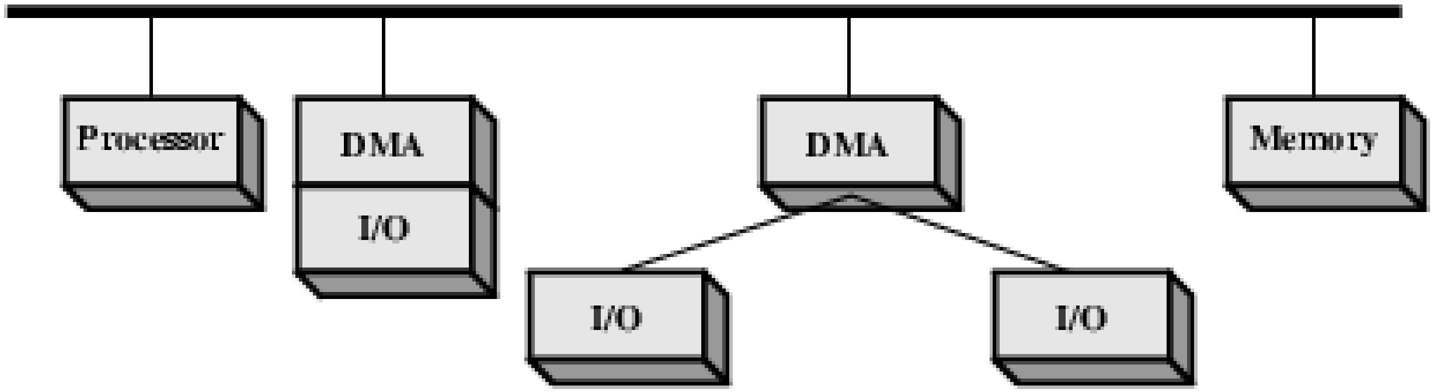


DMA Configurations (1)



- Single Bus, Detached DMA controller
- Each transfer uses bus twice
  - I/O to DMA then DMA to memory
- CPU is suspended twice

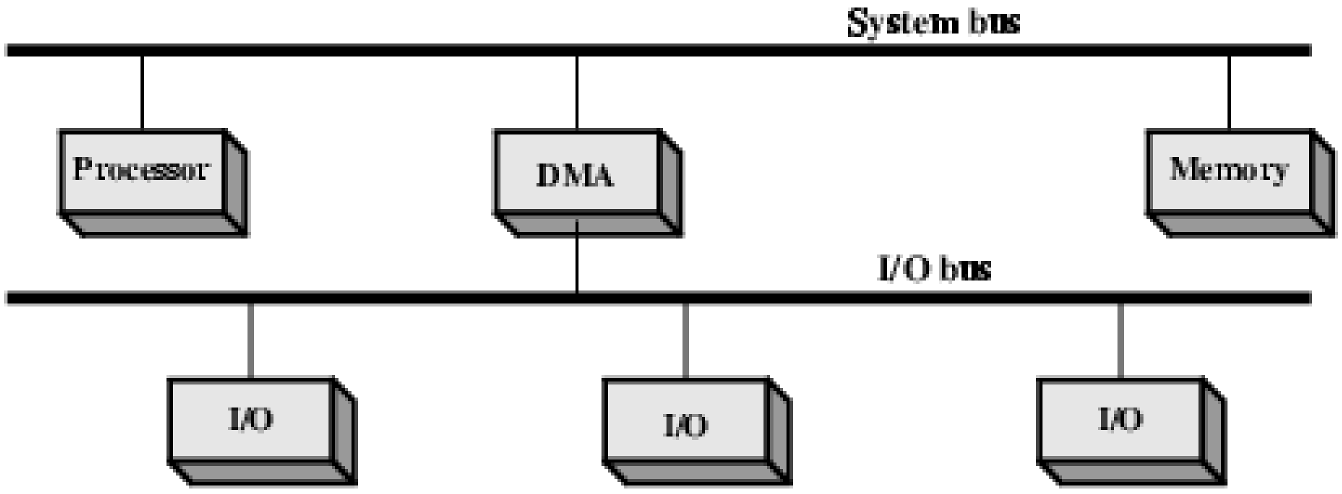
DMA Configurations (2)



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

- Single Bus, Integrated DMA controller
- Controller may support >1 device
- Each transfer uses bus once
  - DMA to memory
- CPU is suspended once

DMA Configurations (3)



(c) I/O bus

- Separate I/O Bus
- Bus supports all DMA enabled devices
- Each transfer uses bus once
  - DMA to memory
- CPU is suspended once

External Devices

- SCSI (Small Computer System Interface)
- FireWire (IEEE 1394)
- USB (Universal Serial Bus)

SCSI

- Acronym for ***s**mall **c**omputer **s**ystem **i**nterface.*
- Pronounced "scuzzy," SCSI is a **parallel interface standard** used by Apple Macintosh computers, PCs, and many UNIX systems **for attaching peripheral devices to computers.**
- provide for faster data transmission rates (up to 80 megabytes per second) than standard serial and parallel ports.
- Can attach many devices to a single SCSI port, so that SCSI is really an I/O bus rather than simply an interface.
- However, SCSI rarely in used because each piece of SCSI hardware has its own host adapter,and the software drivers for the device cannot work with an adapter made by someone else.
- Nearly all Apple Macintosh computers, excluding only the earliest Macs and the recent iMac, come with a SCSI port for attaching devices such as disk drives and printers.

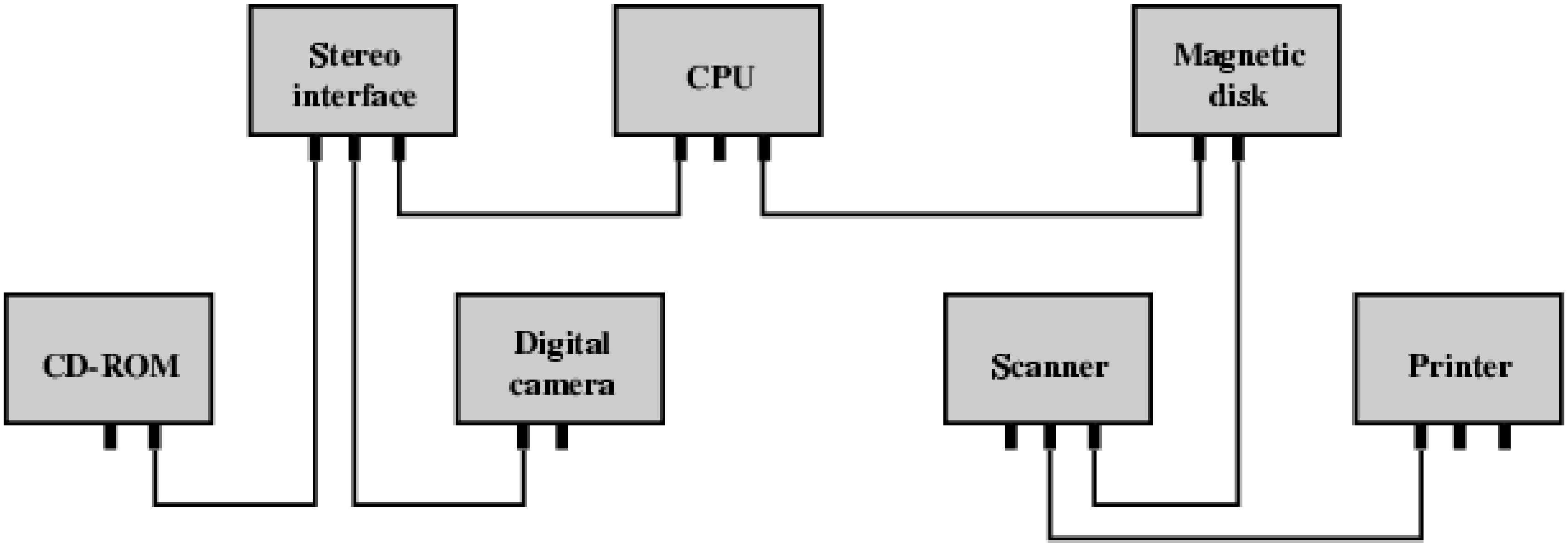
The SCSI Interface

FireWire (IEEE 1394)

- Fire Wire is **Apple Computer's version of a standard, IEEE 1394, High Performance Serial Bus, for connecting devices to personal computer**.
- Uses for devices that need to transfer high levels of data in real-time, such as video devices.
- Fire Wire provides a single plug-and-socket connection on which up to 63 devices can be attached with data transfer speeds up to 400 Mbps (megabits per second).
- Like USB, it also supports both Plug-and-Play and hot plugging, and also provides power to peripheral devices.

FireWire Interface and Symbol

Simple FireWire Configuration



USB

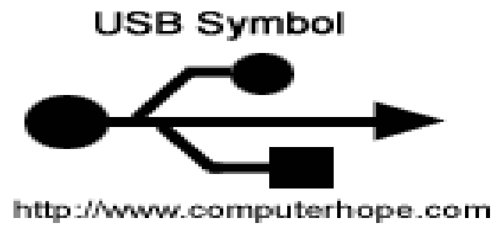
USB (Universal Serial Bus) is **a plug-and-play interface between a computer and add-on devices (such as mouse, scanners, and printers).**

With USB, a new device can be added to computer without having to add an adapter card or even having to turn the computer off.

USB 1.1 supports a data speed of 12 megabits per second. This speed will accommodate a wide range of devices.

It is expected to completely replace serial and parallel ports.

A single USB port can be used to connect up to 127 peripheral devices.



USB connector and symbol

USB Connectors