

record separator (RS) and file separator (FS). The communication control characters are useful during the transmission of text between remote terminals. Examples of communication control characters are STX (start of text) and ETX (end of text), which are used to frame a text message when transmitted through a communication medium.

byte

ASCII is a 7-bit code, but most computers manipulate an 8-bit quantity as a single unit called a *byte*. Therefore, ASCII characters most often are stored one per byte. The extra bit is sometimes used for other purposes, depending on the application. For example, some printers recognize 8-bit ASCII characters with the most significant bit set to 0. Additional 128 8-bit characters with the most significant bit set to 1 are used for other symbols, such as the Greek alphabet or italic type font. When used in data communication, the eighth bit may be employed to indicate the parity of the binary-coded character.

11-2 Input–Output Interface

Input–output interface provides a method for transferring information between internal storage and external I/O devices. Peripherals connected to a computer need special communication links for interfacing them with the central processing unit. The purpose of the communication link is to resolve the differences that exist between the central computer and each peripheral. The major differences are:

1. Peripherals are electromechanical and electromagnetic devices and their manner of operation is different from the operation of the CPU and memory, which are electronic devices. Therefore, a conversion of signal values may be required.
2. The data transfer rate of peripherals is usually slower than the transfer rate of the CPU, and consequently, a synchronization mechanism may be needed.
3. Data codes and formats in peripherals differ from the word format in the CPU and memory.
4. The operating modes of peripherals are different from each other and each must be controlled so as not to disturb the operation of other peripherals connected to the CPU.

interface

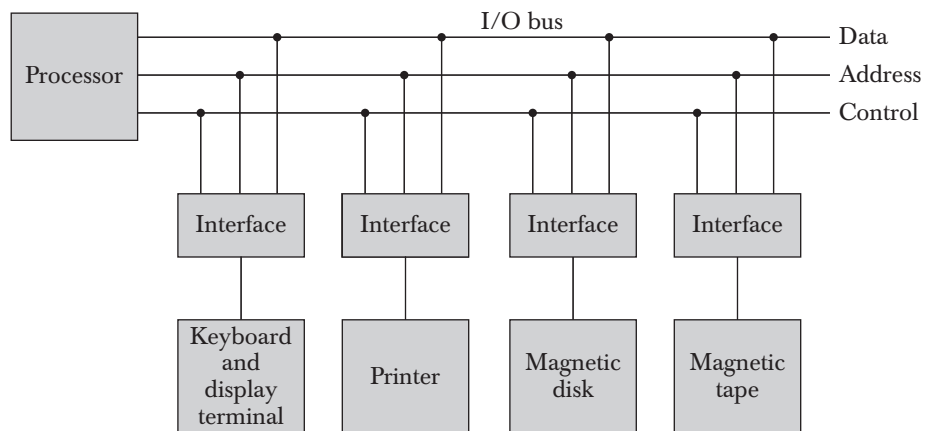
To resolve these differences, computer systems include special hardware components between the CPU and peripherals to supervise and synchronize all input and output transfers. These components are called *interface* units because they interface between the processor bus and the peripheral device. The word “Interface” is a general term for the point of contact between two parts of a system. In digital computer system the interface is referred to as a complementary set of signal connection points between two parts of a system. Therefore, “to interface” means to attach two or more components or systems,

via their respective interface points for data exchanges between them. Two main types of interface are CPU interface that corresponds to the system bus and input–output interface that depends on the nature of input–output device. To attach an input–output device to CPU and input–output interface, circuit is placed between the device and the system bus. This circuit is meant for matching the signal formats and timing characteristics of the CPU interface to those of the input–output device interface. The main function of input–output interface circuit are data conversion, synchronization and device selection. Data conversion refers to conversion between digital and analog signals, and conversion between serial and parallel data formats. Synchronization refers to matching of operating speeds of CPU and other peripherals. Device selection refers to the selection of I/O device by CPU in a queue manner. In addition, each device may have its own controller that supervises the operations of the particular mechanism in the peripheral.

I/O Bus and Interface Modules

A typical communication link between the processor and several peripherals is shown in Fig. 11-1. The I/O bus consists of data lines, address lines, and control lines. The magnetic disk, printer, and terminal are employed in practically any general-purpose computer. The magnetic tape is used in some computers for backup storage. Each peripheral device has associated with it an interface unit. Each interface decodes the address and control received from the I/O bus, interprets them for the peripheral, and provides signals for the peripheral controller. It also synchronizes the data flow and supervises the transfer between peripheral and processor. Each peripheral has its own controller that operates the particular electromechanical device. For example, the printer controller controls the paper motion, the print timing, and the selection of printing characters. A controller may be housed separately or may be physically integrated with the peripheral.

Figure 11-1 Connection of I/O bus to input–output devices.



The I/O bus from the processor is attached to all peripheral interfaces. To communicate with a particular device, the processor places a device address on the address lines. Each interface attached to the I/O bus contains an address decoder that monitors the address lines. When the interface detects its own address, it activates the path between the bus lines and the device that it controls. All peripherals whose address does not correspond to the address in the bus are disabled by their interface.

At the same time that the address is made available in the address lines, the processor provides a function code in the control lines. The interface selected responds to the function code and proceeds to execute it. The function code is referred to as an I/O command and is in essence an instruction that is executed in the interface and its attached peripheral unit. The interpretation of the command depends on the peripheral that the processor is addressing. There are four types of commands that an interface may receive. They are classified as control, status, data output, and data input.

I/O command

control command

A *control command* is issued to activate the peripheral and to inform it what to do. For example, a magnetic tape unit may be instructed to backspace the tape by one record, to rewind the tape, or to start the tape moving in the forward direction. The particular control command issued depends on the peripheral, and each peripheral receives its own distinguished sequence of control commands, depending on its mode of operation.

status

A *status command* is used to test various status conditions in the interface and the peripheral. For example, the computer may wish to check the status of the peripheral before a transfer is initiated. During the transfer, one or more errors may occur which are detected by the interface. These errors are designated by setting bits in a status register that the processor can read at certain intervals.

output data

A *data output command* causes the interface to respond by transferring data from the bus into one of its registers. Consider an example with a tape unit. The computer starts the tape moving by issuing a control command. The processor then monitors the status of the tape by means of a status command. When the tape is in the correct position, the processor issues a data output command. The interface responds to the address and command and transfers the information from the data lines in the bus to its buffer register. The interface then communicates with the tape controller and sends the data to be stored on tape.

input data

The *data input command* is the opposite of the data output. In this case the interface receives an item of data from the peripheral and places it in its buffer register. The processor checks if data are available by means of a status command and then issues a data input command. The interface places the data on the data lines, where they are accepted by the processor.

I/O versus Memory Bus

In addition to communicating with I/O, the processor must communicate with the memory unit. Like the I/O bus, the memory bus contains data,

address, and read/write control lines. There are three ways that computer buses can be used to communicate with memory and I/O:

1. Use two separate buses, one for memory and the other for I/O.
2. Use one common bus for both memory and I/O but have separate control lines for each.
3. Use one common bus for memory and I/O with common control lines.

IOP

In the first method, the computer has independent sets of data, address, and control buses, one for accessing memory and the other for I/O. This is done in computers that provide a separate I/O processor (IOP) in addition to the central processing unit (CPU). The memory communicates with both the CPU and the IOP through a memory bus. The IOP communicates also with the input and output devices through a separate I/O bus with its own address, data and control lines. The purpose of the IOP is to provide an independent pathway for the transfer of information between external devices and internal memory. The I/O processor is sometimes called a data channel. In Sec. 11-7 we discuss the function of the IOP in more detail.

Isolated versus Memory-Mapped I/O

Many computers use one common bus to transfer information between memory or I/O and the CPU. The distinction between a memory transfer and I/O transfer is made through separate read and write lines. The CPU specifies whether the address on the address lines is for a memory word or for an interface register by enabling one of two possible read or write lines. The *I/O read* and *I/O write* control lines are enabled during an I/O transfer. The *memory read* and *memory write* control lines are enabled during a memory transfer. This configuration isolates all I/O interface addresses from the addresses assigned to memory and is referred to as the *isolated I/O method* for assigning addresses in a common bus.

isolated I/O

In the isolated I/O configuration, the CPU has distinct input and output instructions, and each of these instructions is associated with the address of an interface register. When the CPU fetches and decodes the operation code of an input or output instruction, it places the address associated with the instruction into the common address lines. At the same time, it enables the I/O read (for input) or I/O write (for output) control line. This informs the external components that are attached to the common bus that the address in the address lines is for an interface register and not for a memory word. On the other hand, when the CPU is fetching an instruction or an operand from memory, it places the memory address on the address lines and enables the memory read or memory write control line. This informs the external components that the address is for a memory word and not for an I/O interface.

The isolated I/O method isolates memory and I/O addresses so that memory address values are not affected by interface address assignment since each has its own address space. The other alternative is to use the same

memory-mapped

address space for both memory and I/O. This is the case in computers that employ only one set of read and write signals and do not distinguish between memory and I/O addresses. This configuration is referred to as *memory-mapped I/O*. The computer treats an interface register as being part of the memory system. The assigned addresses for interface registers cannot be used for memory words, which reduces the memory address range available.

In a memory-mapped I/O organization there are no specific input or output instructions. The CPU can manipulate I/O data residing in interface registers with the same instructions that are used to manipulate memory words. Each interface is organized as a set of registers that respond to read and write requests in the normal address space. Typically, a segment of the total address space is reserved for interface registers, but in general, they can be located at any address as long as there is not also a memory word that responds to the same address.

Computers with memory-mapped I/O can use memory-type instructions to access I/O data. It allows the computer to use the same instructions for either input–output transfers or for memory transfers. The advantage is that the load and store instructions used for reading and writing from memory can be used to input and output data from I/O registers. In a typical computer, there are more memory-reference instructions than I/O instructions. With memory-mapped I/O all instructions that refer to memory are also available for I/O.

I/O port

Example of I/O Interface

An example of an I/O interface unit is shown in block diagram form in Fig. 11-2. It consists of two data registers called *ports*, a control register, a status register, bus buffers, and timing and control circuits. The interface communicates with the CPU through the data bus. The chip select and register select inputs determine the address assigned to the interface. The I/O read and write are two control lines that specify an input or output, respectively. The four registers communicate directly with the I/O device attached to the interface.

The I/O data to and from the device can be transferred into either port *A* or port *B*. The interface may operate with an output device or with an input device, or with a device that requires both input and output. If the interface is connected to a printer, it will only output data, and if it services a character reader, it will only input data. A magnetic disk unit transfers data in both directions but not at the same time, so the interface can use bidirectional lines. A command is passed to the I/O device by sending a word to the appropriate interface register. In a system like this, the function code in the I/O bus is not needed because control is sent to the control register, status information is received from the status register, and data are transferred to and from ports *A* and *B* registers. Thus the transfer of data, control, and status information is always via the common data bus. The distinction between data, control, or status information is determined from the particular interface register with which the CPU communicates.