MICROCOMPUTERS IN TRANSIT

A Hardware Handbook

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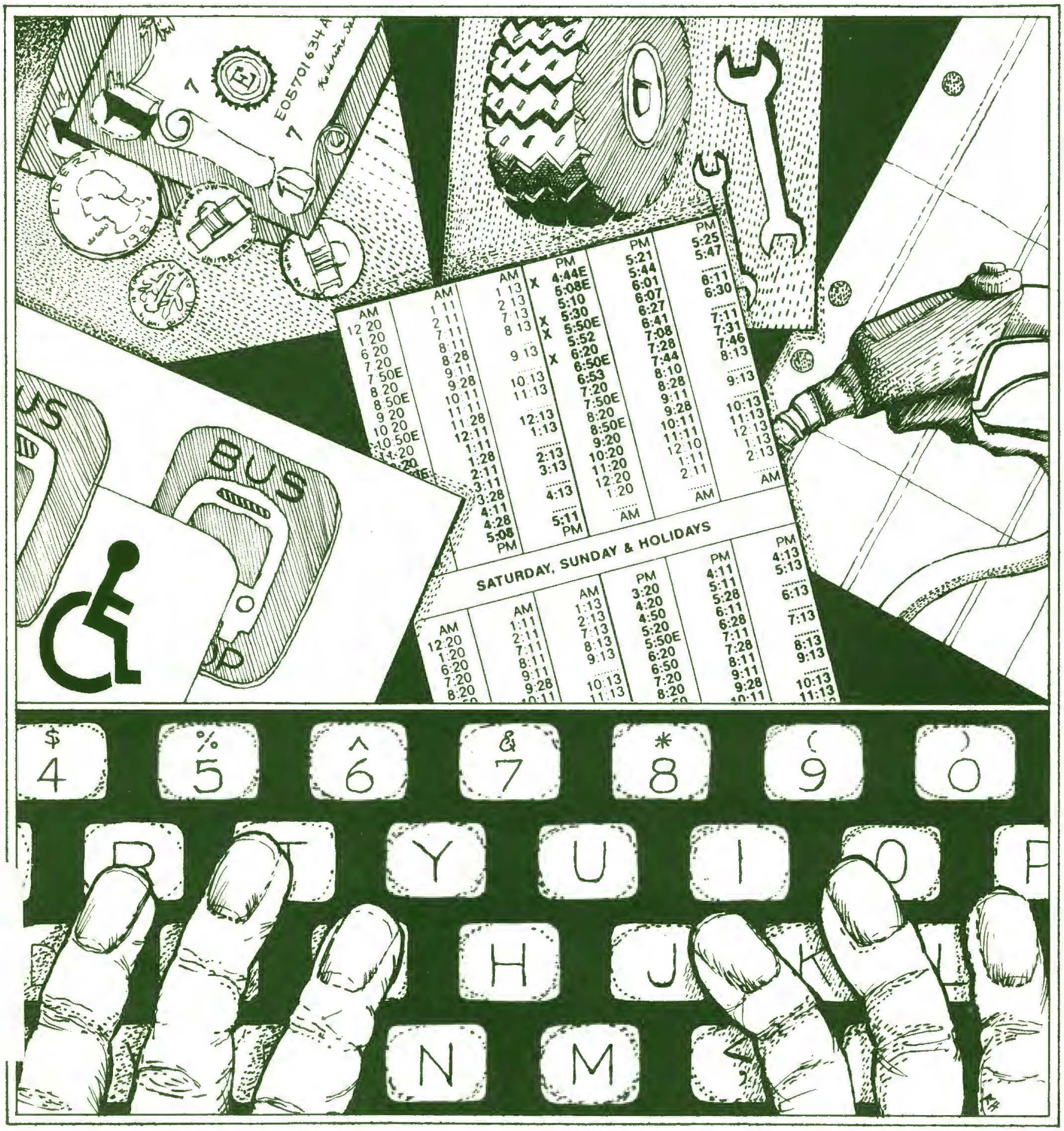

Microcomputers in Transit: A Hardware Handbook

Final Report
July 1984

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16. Abstract

This handbook introduces the management and staff of small to medium sized transit operations to the hardware components of a microcomputer system. It describes the functions of each hardware component, and characteristics to look for in selecting equipment.

Chapter 1 sets the stage by providing an overview of the elements of a microcomputer system. Chapter 2 describes the preparations which should be completed before considering specific hardware items. Chapters 3, 4, 5, and 6 each discuss one of the major components of a microcomputer system, the computer itself, memory, input and output devices and optional enhancements.

This handbook is a companion document to Microcomputers in Transit: A Software Handbook.

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CHAPTER 1

INTRODUCTION

Objectives of the Handbook

Many transit agencies are preparing to purchase a microcomputer for the first time. The microcomputer must be capable of performing useful functions as defined by the transit agency staff, within the specific environment of the organization. Transit managers are faced with a spectrum of equipment which is varied and technically complex. The purpose of this handbook is to describe the range of equipment available, and the considerations for selecting equipment to be used in the transit industry.

The material presented here is intended to be of most use to management of small to medium-sized transit agencies who have identified a need for microcomputers in their agency. It is assumed that the user has little or no prior experience with microcomputers.

The Role of Microcomputers in Transit

Inexpensive, mass produced microcomputers have made the use of computers a real possibility for small to medium-sized transit systems whose limited budgets formerly precluded the application of computers in their operations. Microcomputers, contrary to popular perceptions, have been available for over a decade. The earliest microcomputers were relatively obscure, ill suited for use by those unfamiliar with computer programming, generally slow, and had a restricted range of applications. However, they were quite capable of performing a number of complex tasks. The distinguishing features of today's microcomputers are their (1) broader availability, (2) wide range of applications, and most important, (3) ease of use. Without these last two features microcomputer use would probably remain in the domain of computer programmers and be devoted to specialized, single-purpose tasks. The usefulness of microcomputers is made possible by the development of application programs general enough to meet the needs of many unrelated businesses. These programs are also quite easy to use, reducing the complexity of computer use to nearly the level of skill required for using calculators or typewriters.

The transit industry is rapidly recognizing the promise of this technology, and adopting it accordingly. A substantial number of agencies are using microcomputers for a variety of tasks, and many more are in the process of acquiring one. One of the first areas where many operations realize benefits from their microcomputers is in the application of generic programs. In the longer term, more specialized application programs, either custom developed for a particular agency, or for the industry as a whole, will have profound impact on the management of transit operations.

The "microcomputer revolution" is still underway. Development of new technology, software to take advantage of its capabilities, new concepts in software, and a more widespread understanding of the uses of computers is taking place rapidly. Whatever developments take place in the future, the capabilities of the present generation of technology will take time for the industry to digest.

Components of the Microcomputer System

A microcomputer system consists of three elements: the program or software, the computer itself and its attachments or hardware, and an operating system which links the two. These three elements are mutually supportive, and must all be compatible.

Software

The application program or software, is the reason for computer use. It is the element with which the user comes into daily contact, and which makes the machine either valuable or ineffective for an application. In all selection decisions concerning the system, it is the final application, and thus the application program, which is the bottom line. A program may be purchased or obtained ready-to-use, or it may be written in a programming language by agency staff or an outside programmer for your specific purpose.

Hardware

The hardware is the tool which performs the tasks defined by the program. The core is the computer itself, including the microprocessor, and other equipment within the computer. Additional components, called "peripherals," are attached to the computer. They may include disk drives, the keyboard, monitor, printer, and additional optional equipment such as a modem for communications and a hard disk for data storage. The hardware items must be powerful enough to perform the tasks required by the program within the context of the agency's operation.

Operating System

The operating system is a master program which acts as interface between the hardware and the application software. It controls the hardware as required by the program, and performs a number of fundamental tasks common to all applications. For example, when a program requires printing some data it tells the operating system, which then alerts the computer to send the message and data to the printer. A similar function is performed for the display screen and keyboard. The operating system includes programs which allow the user to perform a number of routine housekeeping tasks, such as copying disks. Operating systems, programming languages, and utilities, which are all programs but have no actual application by themselves, are called "system software." They support the development and use of the actual application software.

A companion handbook, Microcomputers in Transit: A Software Handbook, deals with applications and system software.

Structure of the Handbook

Material is presented in the order in which it is likely to be required in selecting a system. Chapter 2 summarizes the preparation which is required before starting to consider specific pieces of equipment, and discusses general considerations in selecting hardware. Chapter 3 deals with the characteristics of the computer itself. The various types of equipment which are attached to the computer, for communicating with it, storing data, and other purposes, are described in Chapters 4, 5, and 6 respectively. A glossary of technical terms and list of references are included in Appendices A and B.

It is impossible to avoid the use of brand names in this discussion. The mention of any specific brand of equipment in no way implies an endorsement of the product. This document does not attempt to describe all equipment on the market, but rather to present concepts with which the products can be evaluated.

We hope this handbook provides a useful starting point for selecting microcomputer components and clarifies some of the complexities of the subject. Good luck!

CHAPTER 2

BEFORE CONSIDERING HARDWARE

The technology and equipment which make up a microcomputer system are impressive and intriguing, as well as being quite complex. Before becoming involved with the technical aspects of the equipment, you should consider four general issues concerning its selection. First, selection of hardware should only be part of a process designed to provide a microcomputer system which fits the needs of the agency; the software is the more important part of the system. Second, an overview of how the parts of a microcomputer system fit together is needed to understand the requirements of each element. Third, several general considerations apply to the selection of each piece of hardware in the system. Finally, the alternative sources of computer equipment offer advantages and disadvantages. These four issues are addressed in this chapter.

The Selection Process

As a general rule, the selection of a microcomputer system should depend on the availability of programs that will meet the needs of the agency. For this reason, the process of selecting a microcomputer consists of three steps:

1. Assessing the need for automation.
2. Identifying and selecting software.
3. Selecting hardware.

Each of these steps requires a significant amount of time. The time and effort will contribute to more successful integration of the microcomputer and software with the tasks of the organization. A short discussion of the three steps follows. The first two are described in more detail in a companion document entitled Microcomputers in Transit: A Software Handbook.

Step 1: Needs Assessment

The first step in preparing for selecting a microcomputer system is identifying the specific tasks which would benefit from automation. This requires understanding what a microcomputer can contribute in general, and identifying specific applications where the technology can improve the performance of a task.

Benefits of automation. There are three types of tasks that computers are well suited to perform. First, tasks involving long and repetitive calculations take advantage of the computer's speed. Accounting functions are usually of this type. Second, tasks requiring repeated testing of various assumptions or scenarios may be performed efficiently with a computer. Revising a letter and testing a range of fare policies are examples of this. Finally, tasks requiring repeated retrieval and manipulation of large amounts of data make use of the computer's ability to organize and store data. Analysis of data on absenteeism or fluids consumption falls into this category.

The benefits that can be obtained from automation of these tasks are also of three types:

1. **Time savings** may result from faster completion of calculations and maintenance of data. The value of the time depends on whose time is saved. Although staff is unlikely to be reduced, alternative and more valuable uses may be made of employee time. A manager may be freed from the mechanics of problem solving to consider the alternatives and methods more carefully.

2. **Flexibility** is offered to managers, who can use microcomputers to examine a broader range of alternative solutions than could be done manually. The sensitivity of a forecast to various assumptions can be explored.

3. **Additional information** can be provided for more complete monitoring of system performance and more informed decision-making. Data which was previously too cumbersome to summarize in many ways can be rapidly manipulated in response to particular information needs.

Evaluating tasks. Each task that is a potential candidate for automation should be examined carefully for the benefits which may be obtained. Questions which help to identify the type of benefits that could occur include:

1. Are any of the steps in the task appropriate for automation?

2. How much time might be saved?

3. How could automation improve performance of the task, by providing additional useful information, for example?

4. Are staff receptive to using a microcomputer?

5. How is the task connected to other activities which might constrain automation?

Reviewing each task in light of these questions will clarify what, if any, benefits might be expected from automation of the task.

Constraints, such as staff receptiveness and interconnection between tasks, will also be indicated. While it is impossible to quantify benefits in dollar terms for a strict cost benefit analysis, summarizing expected benefits will clarify what is being obtained for the cost of the system.

Step 2: Software Selection

The feasibility of using a microcomputer for the tasks that have been identified depends on the availability of a program that will do the necessary job.

Types of software. There are two broad categories of software:

- General-purpose generic software.
- Application software.

Generic programs are multi-purpose tools which can be applied to a range of business functions. Spreadsheets, word processors, and database managers are the main types of generic programs. Application programs are designed to perform a particular function either in general business or in the transit industry. Accounting software and maintenance management programs are examples of this.

Exploring the range of software which can contribute to agency functions will clarify what microcomputer applications are feasible in your agency. A program to perform some functions may be too expensive for the benefits it is likely to generate.

Selecting software. Finally, specific programs of each type that has been identified should be selected. Five general categories of criterion should be considered in selecting programs:

1. **Technical constraints.** General characteristics of the system may affect the programs which can be included. A hard disk, multi-user system, or compatibility with an existing computer are examples of these constraints.

2. **System considerations.** The parts of the system should work together to provide a well-integrated set of programs flexible enough to meet the present and future needs of the agency.

3. **User considerations.** The programs should be convenient for agency staff to use. Not only should the program itself be easy to learn and use, but it should also fit agency operating procedures with a minimum of disruption.

4. **Application considerations.** Specific technical limitations will apply to each particular application being considered. The program should be able to accommodate the particular conditions of the transit agency.

5. **Cost**. The cost of the program includes hidden elements beyond the purchase price. Staff time for training and learning the application must be considered as well as time for setting up the application and entering initial data.

Step 3: Hardware Selection

The selection of hardware is the topic of this handbook and is addressed in detail in the material which follows. It is important that hardware selection be viewed as one part of the process, the objective of which is to acquire a tool which fits and benefits the agency. The selection of microcomputer hardware should be driven by the applications which will be automated and the software required by those applications.

System requirements. The first level of definition of the hardware requirements takes place during the needs assessment phase. Two characteristics of the system can be identified at this point. The amount and nature of data to be stored will determine the appropriate form of mass storage and the need for a hard disk drive. The interrelationships between the applications and need for sharing data between users will indicate how much coordination between users of the system is needed.

Application requirements. Specific applications may also constrain software selection. If the microcomputer is to be used for word processing, for example, a letter quality printer will be necessary. Graphics require certain types of monitors and printers. In some circumstances, for ridesharing applications for instance, portability may be a desirable feature.

Software constraints. Finally, the programs to be run on the microcomputer may dictate certain hardware requirements. The operating system selected will suggest a family of microcomputers to consider. In some cases a transit application program may only run on a specific machine.

In order to define these effects of the applications on your needs it is essential to have a quite specific plan for the use of the microcomputer before selecting one. The machine itself is of no use without the software to run on it. The software is only as valuable as its usefulness to the agency.

The Anatomy of a Microcomputer System

A microcomputer system is actually a collection of parts as illustrated in Figure 2.1. Each element must be selected to be able to work effectively with the other elements of the system. Buying a microcomputer is somewhat like buying a car with standard equipment and options.

The Computer

The core of the system is the microcomputer itself. The computer is roughly analagous to the amplifier of a stereo system. You can plug a variety of optional pieces of equipment, called peripherals, into the computer in much the same way that speakers and turntables are connected through the amplifier. The microcomputer can be modified with optional enhancements, whereas an amplifier usually can not.

The heart of the microcomputer is the central processing unit, or CPU. This is actually a tiny computer on a "chip." (The INTEL 8088 or Zilog Z80 chips are common ones.) The CPU does all the thinking in the computer, all the calculations, and directs all the manipulation of data.

The CPU is connected to the other parts of the microcomputer by a "bus". The bus moves data and instructions from the CPU to memory or the peripherals. The other parts of the computer are either hooked into the bus permanently, as internal memory is, or connected by means of "slots" which can be used as required to plug in extra components.

The computer itself contains two types of memory. Read only memory (ROM) stores material which is permanently recorded in the computer at the factory. This material is primarily programmed instructions to the computer. Random access memory (RAM) is only active when the computer is turned on. It is used to store programs, data, and other information temporarily; when the computer is turned off it is erased.

Peripherals

Many of the peripherals which can be attached are used for communicating with the computer. The keyboard provides communication from the user to the computer. The monitor and printer allow the computer to communicate with the user. Modems are used to connect two computers to allow them to communicate with each other.

Additional memory, or mass storage, is provided outside the computer by floppy disks or hard disks. In order to use material stored on disks the computer must read it and store it in RAM. Memory can also be purchased for other special purposes, such as facilitating printing.

Controllers

Between the bus and most peripherals is a controller. This controller coordinates the instructions sent by the CPU with the instructions required by the peripheral equipment. In some cases the controller is permanently installed in either the computer or the peripheral. In other cases it must be purchased as a separate circuit board which plugs into one of the slots.

The basic components of a computer system useful for transit applications are:

1. The computer itself (discussed in Chapter 3) including:

    - the CPU,
    - read only memory (ROM)
    - random access memory (RAM)

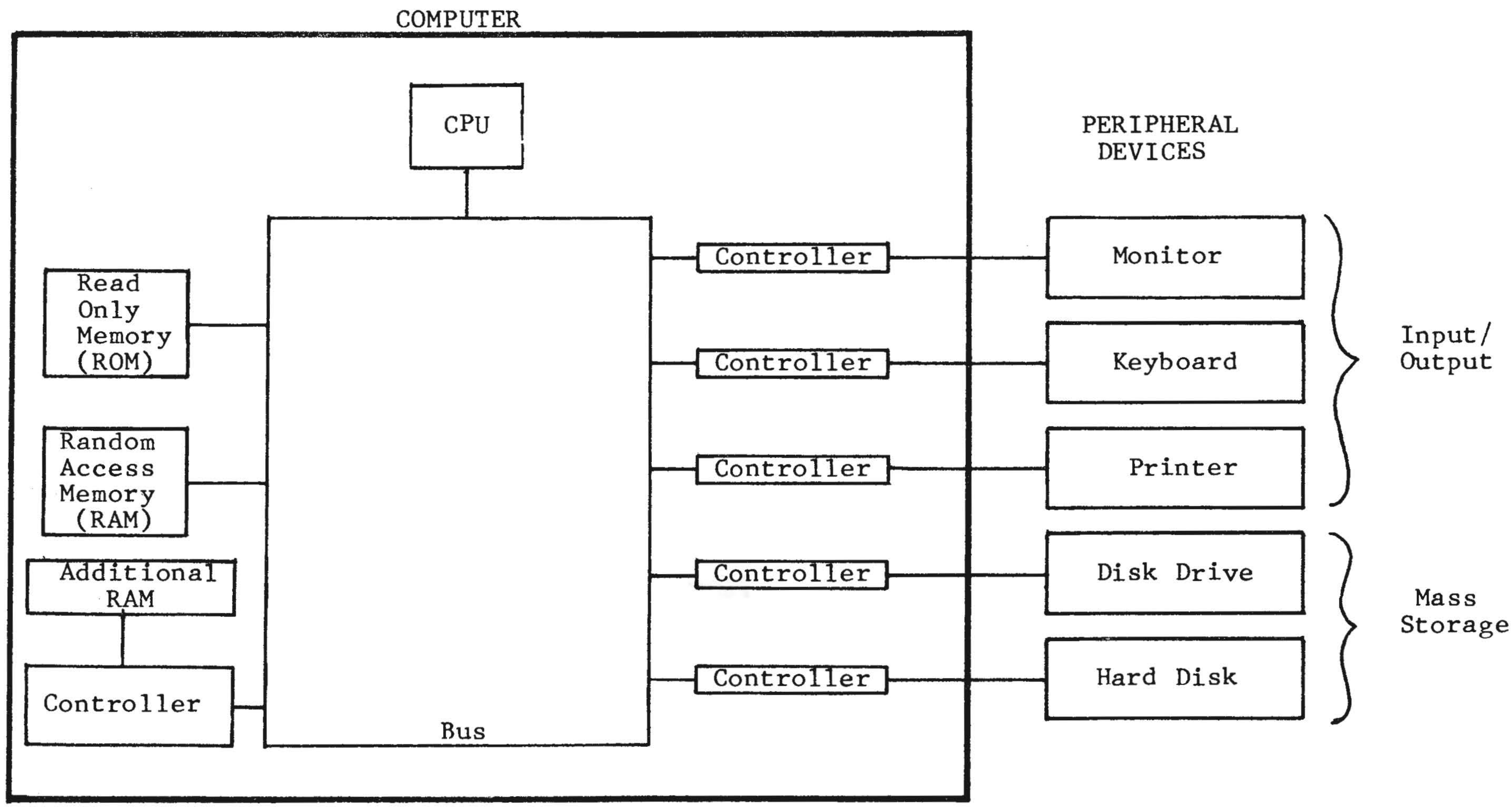

FIGURE 2.1 Components of a Microcomputer

2. Input/Output devices (covered in Chapter 4) such as:

   - the keyboard
   - video monitor
   - printer

3. Mass storage devices (described in Chapter 5) including:

   - floppy disk drives
   - hard disk drives

4. Device controllers and circuitry (discussed in relation to each system component).

How the Computer Works

The interrelationship of the components of the computer can be clarified by a brief image of how the computer works. The operation of the computer can be imagined as a series of relatively simple actions which combine to form the complex task the computer performs. These actions include:

1. Reading instructions from a keyboard, storage device or memory, and executing them.

2. Transferring data from one memory or storage device to another, such as from a disk drive to random access memory (RAM).

3. Outputting the results of a computation by taking the result stored in memory and writing it on a disk for future use or printing it in a report for review by users.

Three common procedures which illustrate the operation of the computer are turning it on, running a program, and turning it off.

Turning on (Booting) the Computer

When the computer is off, all the memory is empty except for the read only memory (ROM). The computer uses the material contained in the CPU and ROM to start itself up again and prepare for applications. This process is called bootstrapping or simply booting the computer.

The computer is turned on by turning on the power switch. As soon as the CPU gets power it looks in ROM for an instruction. ROM may tell the CPU to check various parts of the computer to make sure they are functioning correctly. When this has been completed, the next instruction the CPU finds in ROM tells it to read a file containing the operating system from the disk drive, and to store the contents in RAM. Having loaded the operating system, the computer is now ready for other applications, and waits for an instruction telling it what to do next.

Some computers have the operating system permanently programmed in ROM. This simplifies turning on the computer, because it does not have to read the system from a mass storage device, but is immediately ready for applications.

Running a Program

After booting, the computer is ready for further instructions. Often the next instruction tells it to run a given program. For example, a user might want to run a forecasting program called TRENDS. The CPU looks on the disk drives for a program file called TRENDS, reads the contents from the disk, and stores them in RAM. The program file is actually a list of commands to the CPU. When the computer starts to run the program it starts with the top command, and executes each one until it comes to the end of the program. Each command might be an instruction to read data from a disk, store it in RAM, perform a mathematical or logical function on stored data, store the result, write output on a disk, or print it.

Many commercial programs are read and run automatically from a disk when the computer is turned on. These programs are stored in a file which tells the computer to read it first, as soon as the operating system has been loaded. As a result, the operator does not have to explicitly tell the computer to run the program. This makes the program easier to use.

Turning off the Computer

The computer is turned off by turning off the power. Immediately the operating system, programs, and data that were stored in RAM are erased. All material stored in RAM can be saved by writing it on a floppy or hard disk before turning the computer off. The permanent ROM remains to bootstrap the computer for its next use.

General Considerations in Hardware Selection

The factors which contribute to selection of hardware may be grouped into four types:

1. Application considerations.

2. Compatibility and flexibility.

3. Reliability and support.

4. Cost.

Application Considerations

Requirements are placed on the equipment by the applications for which it will be used. These considerations generally define what pieces of equipment are needed, such as a letter quality printer or a hard disk.

The converse of this relationship is that each piece of the system should have a reason for being there. It should be possible to explain why each element is needed for the system to do the job required of it.

Most of the general requirements of the system will be established during needs assessment and software selection. The operating system selected will limit which computers can be used. A list of data to be stored can be prepared for use in selecting the type and amount of mass storage. The type of printers required will be determined by the amount of word processing and graphics to be done. The amount of RAM required will be known from the software to be used. Communications and multi-user needs will be based on the applications, physical locations of equipment, and amount of use the microcomputers are likely to receive.

Compatibility and Flexibility

In order for the computer to retain its usefulness in the agency it may need to be compatible with other equipment and should be flexible to accommodate future needs.

In many situations it is desirable for a microcomputer to be compatible with equipment in use in other agencies or in the transit industry as a whole. This facilitates sharing of development costs for application programs, sharing of experiences, training on the equipment, and sharing of data and programs. For these purposes computers should be able to run the same programs and operating system. Identical disk formatting may be desired so that programs and data can be exchanged.

This consideration may lead to selection of a popular or commercially successful machine, although it may not be the most technically suitable. Alternatively a computer which is "compatible" with the market leaders may be considered. These are likely to be less expensive, but not all machines designated compatible are truly so. Software packages designed for one microcomputer may not operate properly on compatible equipment. This is due to the basic input output system (BIOS) which is permanently programmed in the read only memory chips of the machines. The BIOS is a proprietary program, protected by copywrite laws, and is unique to each brand of microcomputer. A program may take advantage of certain features of the BIOS of one microcomputer that are not found on the compatible machine's BIOS; those parts of the software package will not work on the compatible machine. This is not much of a problem for the more popular software packages, such as Lotus 1-2-3, but you should check to make sure that software packages you have selected can be used on the compatible equipment you are considering.

If an existing mini or mainframe computer is to be used with the microcomputer it may be desired to use the microcomputer as a terminal to the larger computer. This may limit the selection of microcomputers. Special communications hardware may also be required.

Flexibility is required for the microcomputer to continue to be useful to the agency. New applications may be identified and new technical breakthroughs may be worth incorporating in the system. Although the technology is changing rapidly in this area, a microcomputer which is not state-of-the-art may continue to meet an agency's needs for years. The chances for continued viability of the system are increased if it is one which many people are using, and which will continue to be supported by programmers and developers of new technical products. The exception to this is the case where a microcomputer is being purchased for, and will continue to be used for, a single well-defined application.

Reliability and Support

Once the microcomputer has been incorporated in the daily functioning of the agency, any breakdown could be very inconvenient or even costly. For this reason it is important to consider the possibility when selecting equipment. In general, equipment which is widely used and locally distributed is likely to have a more accessible repair staff than an exotic machine purchased by mail order. The two components of the system which are most likely to fail, due to moving parts, are the disk drives and the printer. Ideally, a source of temporary replacement equipment for use during a breakdown should be available. This is a good reason to maintain internal consistency and duplication when selecting equipment, rather than purchasing one each of several varieties of computer. If one piece of equipment fails, it is helpful to have a compatible back up in the agency. This is particularly important for printers and disk drives, which have more moving parts than other components and are more likely to break down.

It is also likely that minor problems will occur when setting up and using the system. Again, consider whether support is available to answer questions or troubleshoot these problems.

Cost

The microcomputer itself is only one element of the cost of setting up the system. A budget should be prepared including the various costs of setting up the microcomputer system. Other costs include software, staff training, application development and implementation.

It is a good idea to get several hardware cost estimates for more than bureaucratic reasons. Different suppliers may be able to offer different amounts of support, discount rates, or free software with the microcomputer. The process of getting cost estimates provides an opportunity to discuss the available equipment with your suppliers and become more familiar with the alternatives.

The cost of machines with similar specifications does vary, and there are a number of less expensive variations of the market leaders. In considering this alternative the cost savings should be balanced against other less quantifiable attributes of the machine, such as the amount of support available, ease of getting repairs and the likelihood of its being kept up-to-date and supported in the future.

Software is the key to the system's usefulness; it is important to provide ample resources for buying programs. If only generic programs, such as word processors, database managers and spreadsheets, are used a minimum of 15% of the equipment cost will be required for software. If any application software, such as accounting packages or transit-specific commercial programs, are used, their cost could easily be greater than that of the computer itself. Custom programming will be more expensive still.

The staff using your system should be comfortable with it and have immediate access to at least one person with a good general understanding of the machine's operation to ensure its usefulness. For this reason it is important to provide an appropriate amount of training to users. Depending on individual requirements, this may be a transit-specific training course, a course at a computer store on a particular program, or a more technical course on microcomputer operation. In addition to the direct costs of training, early sessions with the computer may be unproductive and time-consuming, a hidden cost that should be recognized.

The development of applications for your agency is an essential task in making the system useful. In some situations agency staff may have the time to dedicate to this process, as well as sufficient understanding of the software to use it effectively. In other circumstances it may be worthwhile to hire someone to work with the future user of the application in developing it; this ensures more rapid use of the system, and may also provide an opportunity for staff to learn about the system operation.

Some applications require a large amount of initial non-programming work in setting them up. For example, the current list of clients may need to be entered, or the chart of accounts may need to be set up before using an accounting system. This non-technical work creates a barrier to implementing the system, as well as demoralizing staff on their first contact with the microcomputer. Temporary staff can be used to complete these tasks in a timely way without disrupting day-to-day operations.

The cost of a microcomputer system includes these elements in addition to the cost of the hardware. They should be estimated prior to determining how much is really available for purchasing the equip-ment itself.

Buying the Microcomputer

In most cases, equipment can be purchased at a local computer store or from a mail order house. Although you are likely to have some problems with many computer stores, ongoing dealer support will be close at hand. However in some situations, substantial savings can be obtained by mail ordering.

Retail Computer Stores

The microcomputer industry is changing rapidly, and this is reflected by many retail outlets. The sales staff must handle a large number of constantly changing products and cannot be familiar with them all. Be prepared to ask as many questions as you need to become comfortable with your selection, and expect to wait for some answers. Take time with demonstrations of equipment in the store, or find other owners of the equipment with whom to discuss it. Sales staff may also suggest products which have been announced or are newly on the market but have not yet been delivered. Whenever possible avoid purchasing equipment which will have a delivery delay; otherwise, expect a long wait.

An advantage to working with local computer dealers is that they will be able to provide support for your system. If your equipment malfunctions they may be able to provide a replacement machine until your computer is repaired. Answers to your questions and early difficulties should also be available.

Shop around at a number of stores. The inventory any one store can maintain is limited, so you are likely to find different products at the different stores. You may also be able to get a discount from list prices at some outlets.

In general it is preferable to purchase all hardware from the same supplier, even though some cost savings may be available by purchasing components separately. One of the more troublesome aspects of assembling a system is making sure that the various elements work together; if they are all obtained from the same source it is clear where to go for help. This also helps to establish a more supportive relationship with the supplier.

Mail Order Houses

Mail order houses, which advertise in many microcomputer magazines, may be good sources for some elements of your system. Try to check the reputation of a mail order operation by exploring the length of time it has been in business and the availabil-ity of technical support by phone. Mail order houses usually offer healthy discounts on their merchandise; however, support is far away if problems arise. For this reason they are best for supplying standard or often used components which you are confident about installing yourself.

CHAPTER 3

THE COMPUTER

The heart of the microcomputer system is the microcomputer itself. The microcomputer determines the character of the system as a whole and coordinates the various peripheral devices which may be hooked up to it. The elements of interest in choosing a computer are the central processing unit (CPU), random access memory (RAM), expansion slots, and several optional add-ons.

Central Processing Unit (CPU)

The central processing unit (CPU) is a microprocessor which is the brain of the computer. Each microcomputer on the market is built around the CPU selected by its designer. The operating systems are also written for specific CPU microprocessors. There are less than ten CPU microprocessors which are used in many microcomputers at this time. As a result, most microcomputers can be grouped into families sharing a common CPU microprocessor and operating system. Choosing the CPU of a microcomputer effectively determines which family of microcomputers and operating system will be used. In fact, the decision is likely to occur the other way: choosing the operating system will determine the CPU and family of microcomputers which is appropriate.

A microprocessor itself is a miniature computer. It performs the functions of thousands of transistors and connecting circuits, which are etched as an integrated circuit onto a silicon crystal chip in a photographic miniaturization process. While it is possible to create a microcomputer based on a single microprocessor, most microcomputers contain several microprocessors, each one designed to perform a certain task, coordinated by the central CPU microprocessor.

The CPU is the work horse of the microcomputer. It converts programs into the basic form useable by the microprocessor and either carries out the duties or parcels them out to other microprocessors. The CPU also directs the flow of information from the input devices, such as the keyboard, to the output devices, such as the printer or monitor.

Types of CPU

The two attributes which differ between CPUs are bit size and clock speed. Both determine the speed and computational abilities of the microprocessor.

Bit size. All data and instructions to the computer are made up of bits (Binary Digits). Each bit is a single digit which can be either only a 1 or a 0. The individual bits are handled in groups of 8, called bytes. Each byte represents one character of information (a letter, symbol, or digit) to the computer. The bit size of a CPU is the size of the unit of information that the computer can work with and determines the speed of the computer and the total amount of memory that it can use. The higher the bit size of the microprocessor, the faster it can process information. A chip which processes data 16 bits, or 2 bytes, at a time is faster than an 8 bit chip.

Most microcomputers in use have 8 bit microprocessors. Sixteen bit microprocessors are becoming more common, and 32 bit microprocessors are just beginning to enter the marketplace. More complicated are the 8/16 bit microprocessor, such as the Intel 8088, and the 16/32 bit microprocessor, such as the Motorola MC 68000. An 8/16 bit chip is a 16 bit microprocessor but the data bus, which carries information to and from the CPU for processing, is only 8 bits wide. When two 8 bit parcels of information are received by the 8/16 microprocessor, they are combined and processed as one 16 bit parcel of information. Once acted upon, the result is broken down into 8 bit parcels and sent out on the data bus for the appropriate output device or memory location. As is to be expected, this 8/16 bit microprocessor is marginally slower than a 16 bit CPU with a 16 bit data bus but it is faster than an 8 bit CPU with an 8 bit data bus. Likewise, a 16/32 bit microprocessor is a 32 bit processor internally with a 16 bit external data bus.

The rationale underlying the use of a narrower data bus by manufacturers is principally that of software availability. The first set of successful microcomputers were based on an 8 bit microprocessor. Due to the widespread acceptance of these 8 bit machines and the length of time they have been on the market, a very large number of commercially successful software packages are available. Microcomputer manufacturers introducing new machines to the market wish to use 16 bit microprocessors and also make their new machines as compatible as possible with the software already available. By staying with the 8 bit data bus, the newer generation of computers can run the older software with minor modifications. New software, taking advantage of the microprocessors' 16 bit capabilities can then be developed at a more leisurely pace.

The 8 bit microprocessors found in most microcomputers include the Zilog Z-80 and Z-80A, the CBM 6502 (formerly MOSTEK 6502) and 6502A, and the Intel 8080 and 8085. The two most commonly found 8 bit microprocessors are the Z-80 (Z-80A) and the CBM 6502.

True 16 bit microprocessors, that is, those which have a 16 bit CPU and a 16 bit data bus, are comparatively rare. The 16/16 bit microprocessors are the Intel 8086, the Zilog 8001, and the DEC PDP-11/23. Far more common are the microcomputers which use the 16 bit microprocessor with an 8 bit data bus. Virtually all of these machines rely on the Intel 8088 CPU.

Microcomputers with 32 bit microprocessors and 16 bit data buses are now becoming available. The few machines which are presently available generally use the Motorola 68000 CPU. Zilog produces the Z8000, a 16/32 bit chip, which is found in a few machines. Exceedingly rare in the market place are true 32 bit microcomputers. Those that are available use proprietary 32 bit microprocessors and have a restricted range of commercially available applications. These machines are primarily oriented towards the scientific application market, and, for the present, need not concern transit systems. In the future though, you may expect to find a wide availability of the true 32 bit machines. The most usual CPU chips are summarized in Figure 3.1.

Clock speed. Clock speed is of importance when discussing the speed of a CPU, for the clock determines the frequency of occurrence of an activity performed by the CPU. The clock speed is measured in megahertz, or million cycles per second. Typical clock speeds found in microcomputers range from slightly over 1 megahertz to 8 megahertz and the Motorola 68000 has a clock speed of 10 megahertz. With all else being equal, a computer with a 4 megahertz clock will be roughly twice as fast as one with a 2 megahertz clock. Some computer manufacturers use a separate clock chip to control the CPU. Others use a CPU with a clock built into the chip.

Selection Considerations

Two interrelated characteristics of the CPU which are important in the selection of a microcomputer are the operating system it uses, and the bit size of the machine. The clock speed is also important for some specialized applications.

Operating system. If a needs assessment and selection of software have been completed, the operating system which is needed will have been identified. Since operating systems are written for a specific microprocessor, specifying an operating system will limit the candidate microcomputers to the family of machines using that microprocessor.

Generally speaking, the popular 8 bit microcomputers use the CP/M (control program/microcomputers) operating system, developed by Digital Research. The 16 bit machines (both 8/16 and 16/16) are most commonly found with a version of MS-DOS (disk operating system) developed by Microsoft. The 32 bit machines currently available use proprietary operating systems, although it is expected that the UNIX operating system developed by ATT's Bell Labs will be widely used in the future. The Apple and Radio Shack microcomputers use their own proprietary operating systems.

Bit size. The bit size is the most significant difference between microprocessors. The bit size affects two characteristics of the computer which are interesting to the user, speed, and amount of memory. The operating system written for a CPU microprocessor is limited by the physical capabilities of the CPU.

CPU Microprocessor Chip	Bit Size	Manufacturer	Operating System	Computers Using the Chip
Z80	8	Zilog	CP/M	Commodore 64, Osborne
CBM6502	8	Commodore Business Machines	Apple DOS	Apple II family
Intel 8088	8/16	Intel	MS-DOS™	IBM-PC and compatibles
Intel 8086	16	Intel		
Motorola 68000	16/32	Motorola	UNIX Proprietary operating systems	Altos

FIGURE 3.1 Summary of CPU Chips

The higher the bit size of a microprocessor, the faster it is. For many applications the speed of the CPU has little significance; the length of time it takes to do a task is constrained by the speed of using the keyboard, printing, reading data from and writing to disks, and the design of the programs being used.

There are two exceptions to this. The first is an application requiring many computations, such as statistical analysis of large amounts of data. For this specific type of task, the time used by the microprocessor to perform the calculations could become a significant portion of the total time to do the task. A second condition requiring high speed occurs when a single CPU microprocessor is being used by several people at the same time as a multi-user system. In this case a slow CPU cannot keep up with the needs of the users at their separate keyboards. Each user will notice a delay while the CPU finishes other users' work. For this reason multi-user systems use 32 bit CPU microprocessors, which are fast enough that a number of users can share them without delays. In some circumstances, 16 bit microcomputers can be shared by two or three people without serious delays.

The amount of random access memory which can be used by a CPU is also related to the bit size, as is discussed later in this chapter. Early 8 bit computers had insufficient memory for many applications. However 16 bit and 32 bit microcomputers are capable of providing ample memory for most applications.

Clock speed. For most users the clock speed of a CPU microprocessor does not make much difference. The slowest ones are so fast that delays caused by them are imperceptible. Speed may become significant for rare applications involving many complex calculations.

Memory

The second element of interest in a microcomputer is memory, which is needed to store programs, data, and intermediate results. The memory that is found in microcomputers stores information on silicon chips. The two types of memory used in microcomputers are read only memory (ROM), and random access memory (RAM).

Read Only Memory (ROM)

Read only memory has a set of permanently programmed instructions which, in the simplest case, activates the various parts of the computer and prepares the CPU for work when the computer is first turned on. Other ROM devices may have the instruction set for an entire programming language, such as BASIC, or an operating system, permanently programmed into them.

Two special examples of ROM are being developed and may be increasingly used in microcomputers. Programmable read only memory (PROM), and erasable programmable read only memory (EPROM) devices are similar to ROM, in that they store a basic set of instructions which the computer or peripheral devices will always need in order to perform useful work. Unlike ROM, in which the instructions are programmed at the factory, PROM and EPROM are programmed by the user. Once a PROM device has been programmed to perform certain duties, it will always perform the duties unless and until the unit fails. EPROM devices, also user programmable, allow the user to erase the instructions currently residing in the chip, usually by exposure to ultraviolet light, and the chip may then be reprogrammed to perform a different set of tasks. PROM and EPROM are not yet commonly used in microcomputers.

The use of ROM is usually fixed for a given computer, and it is not necessary to make any decisions about it. It is helpful to have an understanding of it, because the special characteristics of some new machines make use of it. In some situations a large amount of material, such as the operating system and some programs, is permanently programmed in ROM. This helps to make a machine easy to operate; you turn it on and it is immediately ready to use, without loading a program. Other machines provide locations where ROM chips containing programs can be plugged in, instead of loading the programs from diskettes.

Random Access Memory (RAM)

Random access memory, like ROM, stores instructions telling the CPU what to do, and also stores data values and intermediate calculations and results. The user must load programs or data into RAM before using them. The CPU will fetch the appropriate value or instruction from RAM as needed. Unlike ROM, any instruction held in RAM is lost when the computer is turned off, or if power is interrupted for any reason.

RAM requirements. The amount of RAM needed in a microcomputer system can be determined from the programs which will be run and the amount of data to be manipulated. The RAM has to hold:

1. Certain elements of the operating system.

2. Most, if not all, of a program being run.

3. Data being used with the program.

4. Work space for storage of interim calculations.

Most commercial programs specify how much memory is required, and the maximum amount of memory the program can use. Each program manages the memory differently; some shuffle program elements and data in and out of RAM as needed to reduce the amount of RAM they consume. The minimum amount of memory the computer should have is 192k, and 256k should be sufficient for virtually any application.

RAM capacity. The amount of memory a computer can have is dependent on two factors: the address bus and the microprocessor. The address bus is similar to the data bus, mentioned previously, but instead of carrying data, the address bus carries information concerning the location of a particular memory cell. The wider the address bus, the greater the total number of locations in memory that can be individually specified.

The microprocessor itself is important in determining the total amount of memory that a computer system can have. An 8 bit microprocessor can directly address only 65,536 memory cells (64k), where each cell holds 1 byte or character of information. A 16 bit processor with an appropriately wider address bus can address over one million memory cells. A 32 bit processor can address over 4 million memory locations.

Some 8 bit microcomputers have more than 64k of memory. An 8 bit processor can actually only address 64k of memory. Use of more than 64k is accomplished by means of "paging," which is analagous to the pages in a book. Each page can only hold so much information; once a page is full, a new page is activated. To the computer it is as though all memory cells were erased and it is starting with a clean slate. In order to use information on previous pages, the computer must turn back to the earlier pages which slows the computing process. If an application requires more than 64k of memory (as many software packages do), the programmer will try to reduce the number of page turns needed. The user may not even be aware of the increased time required to run a program of this type. A poorly designed program may switch pages very often, which will result in a considerable increase in program execution time.

Adding RAM. Most microcomputers come with 64k or 128k of memory and have sockets where additional memory chips can be plugged in to increase the memory beyond that which comes with the computer. Early memory chips had a 16k capacity. New chips have a 64k capacity, and there should be 256k chips on the market soon. Thus optional memory can be added in increments of one chip. Chips of 64k give total memory of 128k, 192k, 256k, and so on. When the sockets provided have been filled, an expansion board can be purchased to plug into one of the slots on the bus. This board provides spaces for additional memory chips, as required.

Expansion Slots

Expansion slots are used to plug in boards providing optional enhancements to the computer. The "boards" are epoxy resin boards containing circuitry and chips which may be:

-a program or language
-additional memory
-the controller for a peripheral device (monitor, printer, etc.)
-another component

The total number of peripherals and features that can be included in a computer system is limited by the number of expansion slots in the basic computer unit.

Some computer models preclude expansion altogether, by providing no expansion slots, while others limit the number of peripherals that may be added. As a rule, computer models which include expansion slots are preferable to those which do not include expansion slots. The uses of expansion slots depend partly on what features are provided as permanent parts of the computer. Some computers may require the use of one expansion slot for additional memory, another for disk drive controllers, a third for a video monitor controller to display graphics, and a fourth for a printer. Other computers may provide these essential elements, leaving all the expansion slots for optional equipment.

Given that the virtue of a microcomputer is its limited size, the number of expansion slots on any microcomputer must be restricted for this reason. Manufacturers have introduced multi-function boards for peripherals, so that one expansion slot may serve several purposes. Some popular peripheral boards include additional memory and both parallel and serial ports (described under Add-Ons), three features which separately would have required three expansion slots. By having a clear idea of what you want a computer to do for you before you buy one, you will be able to select that particular set of equipment and peripheral devices which will allow you room for future expansion to meet your needs.

Add-Ons

Several types of options may be incorporated in the microcomputer to tailor it to the needs of the system or to enhance its capabilities. These include: data transmission adapters, cables, coprocessors and multi-processors.

Data Transmission Adapters

A microcomputer needs to have at least one adapter, or port, for communication with a printer or modem. Data transmission adapters are essentially sophisticated outlets into which multi-wired connecters to peripherals can be plugged. These adapters are of three types:

-serial (or asynchronous)
-parallel
-IEEE-488

Some computers include a serial output device or parallel output device, or both. On other systems a serial or parallel output/input port is an optional accessory, in which case you will need to purchase one. These devices plug into the system bus. The relative merits of the two types of ports for printers are described in the section on printers.

Parallel ports. A parallel adapter is used to plug in many of the more recent printers. The standard parallel output device is a Centronics configuration. Non-standard parallel output configurations are typically proprietary. If you have a choice, choose the Centronics standard, which will fit a much wider variety of peripheral devices than a non-standard port.

Serial ports. Serial adapters are used to plug in modems (for communications) or some of the older printers. Two computers can sometimes be connected directly by using serial adapters. The serial, or asynchronous, output/input port has a standard called RS-232. Selecting the industry standard will assure the widest choice of compatible peripherals.

IEEE-488. One other output/input interface device which is standardized, though less commonly found, is the IEEE-488 Connector. There are a number of peripheral devices which use this form of conversion, including disk drives, printers, and plotters. The IEEE-488 standard is slightly different from either the parallel or serial connector in that the IEEE-488 is a bus network, similar to the data bus and address bus. Since the IEEE-488 connection is a bus, several peripheral devices may be attached to a single IEEE port, unlike the parallel and serial ports, which only allow one peripheral device to be attached to a single port.

Cables

The various components of the microcomputer system are connected by cables. Because of the many types of adapters and plugs in use there are many different cables to match the possible combinations. The cable must fit the plugs at both ends, and each pin or hole at one end must be correctly matched with each pin or hole at the other end.

Once you have identified the computer and peripherals you require, check with your supplier to make sure that the necessary cables are included. Cables may come with elements of the computer you purchase, or it may be necessary to purchase some separately. For common configurations or standard equipment this is straightforward. When buying unusual equipment with nonstandard interfaces special cables may need to be ordered.

Coprocessors

Special purpose microprocessors, which are required only for a few special applications, are called coprocessor chips. These chips are designed to perform certain specialized tasks, such as numeric processing or word processing on the chip itself. Programs may be written to perform the same functions on a general purpose microprocessor but the coprocessor chips are faster and more accurate than the program would be.

In a coprocessor system, the primary microprocessor (the CPU) receives all of the information. On the basis of the information received, this microprocessor either processes the information or sends it to the coprocessor better suited for the task at hand.

The most common coprocessor chip is the Intel 8087. The Intel 8087 is a numeric processing chip, which can accommodate very precise numbers represented by 80 bits. The Intel 8087 has a number of mathematical functions built into the chip. This feature, as well as the wide number range obtained using 80 bits results in extremely quick computations and very precise results. If your application requires mathematical modelling or statistical analysis, the Intel 8087 chip may be desirable. In order to take advantage of the capabilities of the Intel 8087 chip, the software used must be written to make use of it explicitly. Some computers provide an empty socket where the Intel 8087 chip can be plugged in.

Coprocessors can also speed up processing. The microprocessor used by IBM runs at 4 megahertz. One manufacturer has produced a replacement board for the IBM-PC which replaces the Intel 8088 microprocessor running at 4 megahertz with the Intel 80088 running at 10 mhz, resulting in a much faster operating speed. For unusual applications involving extremely large databases, this option may be useful.

Multiprocessors

A multiprocessor system contains two or more primary microprocessors, or CPUs. At any time one of the microprocessors is acting as the CPU. Being able to switch from one microprocessor to another gives the effect of having two different computers in one machine.

The most common reason for a multiprocessor configuration is to gain access to programs written for more than one microprocessor/operating system combination. As the 8 bit microcomputers have been available for the longest period of time, many commercial software applications have been developed for them using the CP/M operating system. While there is an expanding number of software application packages available for the 16 bit machines, written to be compatible with MS-DOS, there is still a gap in software available for the new 16 bit machines.

Multiprocessor microcomputers. To be able to use both pools of software, a growing number of new machines are available that have both an 8 bit microprocessor (e.g., Z-80 or CBM 6502) and a newer 16 bit microprocessor (e.g., Intel 8086 or 8088). This allows the use of both CP/M based software and MS-DOS based software.

A multiprocessor configuration does not double the computing power of a machine. Only one CPU is active at any given time. There are economies associated with a multiprocessor system: the two CPUs share the same memory and peripherals. Before the advent of the multiprocessor system, a user wanting software applications using both CP/M and MS-DOS had to buy two different machines with their attendant peripherals and memory. While a multiprocessor system is more expensive than a single processor system, it may be cheaper than two separate systems.

Multiprocessor boards. A similar result can be obtained with a multiprocessor board. It is installed in one of the expansion slots of your computer. A multiprocessor board will essentially result in your having two different computers in one machine and open up a new series of software packages capable of operating on your machines. For example, if you decide on an IBM-PC with its Intel 8088 microprocessor, there are multiprocessor boards available which have the Zilog-80 microprocessor, allowing you to run CP/M Programs. There are also multiprocessor boards which have the CBM 6502 microprocessor allowing the use of Apple software. The usefulness of some of these boards may be limited by their compatibility with various components of the system.

Parallel processors. A different type of multiprocessor configuration is currently being explored by some equipment manufacturers. This is a parallel processor configuration. In this design, two or more identical microprocessors are assembled in parallel, with each microprocessor only performing a portion of the total number of tasks. Parallel processing increases the speed of the computer and also allows for a greater number of complex tasks to be performed. Thus, two or more of the cheaper 16 bit microprocessors in parallel can approach the speed and enhanced operating design features of the newer, more expensive 32 bit CPUs.

CHAPTER 4

COMMUNICATING WITH THE COMPUTER

A microcomputer consists of much more than simply a microprocessor. Unless there is some way to tell the microprocessor what to do and some way for the microprocessor to tell you what it has done, a microprocessor is virtually useless. There must be some form of information input and output devices, even in the simplest of microcomputers. The most usual input device is the keyboard, while output devices include monitors, printers, and plotters. In purchasing input and output devices, it may also be necessary to consider the controllers for each device. In some cases the controller is provided as part of the microcomputer unit; however, frequently the controller must be purchased separately for non-standard peripheral devices.

Keyboards

The most common input device for a microcomputer is the keyboard. The keyboard is the primary way that the user gives information to the computer. Almost all instructions and data used by the computer are typed in through the keyboard at least once. Most microcomputers include a keyboard as standard equipment. Keyboards can also be purchased separately if the one provided is not satisfactory.

Types of Keyboard

There are a surprising number of variations between keyboards. IBM alone makes over 150 different keyboards. Each keyboard has its own combination of overall design, key layout, key mechanics, and internal elements. The first two of these are of most interest to the user. Unlike a typewriter keyboard, which is strictly mechanical, the microcomputer keyboard is an electronic device. When a key is depressed, an electrical impulse is transmitted to the CPU. Most keyboards have a buffer, or small amount of memory. This memory stores a series of key actions, then sends them all as a group to the CPU. This allows for more efficient operation of the CPU.

Keyboard design. The two popular methods of connecting the keyboard to the computer are incorporating the keyboard in the computer unit and attaching a separate keyboard to the computer by cable. IBM has recently introduced a cordless keyboard, which is physically detached from the computer. Information is passed from this keyboard to the CPU by an infrared light beam.

Keys. In addition to the keys found on typewriters, computer keyboards have specialized keys to give the user more convenient control of the computer. The number of keys provided can make the keyboard crowded and confusing.

The core of most computer keyboards is the standard QWERTY typewriter keyboard. Variations are made on this to provide some extra capabilities. Some keyboards, for example, only type upper case letters; the shift key changes the letter keys into computer control functions. Often punctuation keys are rearranged to make space for mathematical signs, such as > or <. The position of some keys, such as return, shift, and shift lock may vary between keyboards.

Three types of special purpose keys are often provided. A number pad, like the keys on a calculator, helps to enter numerical data. Special keys are often provided to move the cursor, which indicates where on the screen text is being entered. Other keys, such as "Escape," "Control," or Delete" give commands directly to the computer.

Some keyboards have special function keys. These keys have common functions or commands pre-defined, or the user may define commands. These special function keys are useful, for a single special function key entry may replace several key entries. As an example, a single key stroke may enter the command "LIST", causing the computer to print a program. This single key entry replaces the four separate key entries required when spelling out the command "LIST" each time you wish to list a program. Certain software packages make extensive use of these special function keys. While not a necessity, special function keys increase the utility and efficiency of a keyboard.

Selection Considerations

For a frequent user, preference between attributes of the keyboard is often a matter of personal taste. Most people just get used to the characteristics of a particular keyboard. However, there are some designs which are generally preferable to others. As the keyboard is the primary means you have of communicating with the computer it should be as trouble free and convenient as possible. The three attributes of a keyboard which should be considered in microcomputer selection are user comfort, key layout, and touch.

User comfort. The choice between a detached keyboard or an integrated keyboard affects the comfort and convenience of microcomputer use. An integrated keyboard allows the operator to use the computer from only one position, which may be tiring or uncomfortable. A detached keyboard allows the user to change positions easily, and can be oriented by the user to achieve a greater amount of efficiency. Some keyboards can be adjusted to an angle similar to that of a typewriter keyboard. For lengthy touch typing the height and angle of the keyboard are particularly important.

Keyboard layout. The key layout is important in determining the convenience of a keyboard. Knowing the uses of the computer will help. If the computer will be used frequently for word processing, a keyboard design that approaches that of a standard typewriter and is familiar to touch typists should be selected. If the primary purpose of the computer will be to enter data, a number pad on the keyboard is a useful feature. For use of some programs, particularly spreadsheets, separate cursor control keys are very convenient.

The placement of certain crucial keys is also important. A key whose function is to escape from the program or erase the work just entered should not be placed too close to a commonly used key, in order to prevent the user inadvertently hitting the escape or delete key, and wasting a long session at the computer.

A keyboard which has multifunction keys, whose meaning is changed by a shift or shift lock (e.g., shift for upper case letters), should have an indicator that shows whether the shift key is active or not.

Touch. Many microcomputer users are sensitive to the way the keys feel when depressed. They should be easy to type. On the other hand it is reassuring to have a decisive feel or click when the key registers. Touch is largely a matter of personal taste, and is most important to touch typists.

Other Input Devices

In addition to keyboards, several other specialized input devices are on the market. Some of these, such as mice, light pens, and touch screens, are "pointing" devices which are used primarily for cursor control to select choices from a screen menu. Optical scanners may be useful for certain data gathering, but the applications of the others in transit are very limited.

Mice

One pointing device, known as a "mouse," is a hand-held instrument which controls the screen cursor. The mouse is moved over a flat surface. The motion is converted to signals which are used by the CPU to move the cursor in the direction of the mouse's movement. Mechanical mice have a small bearing on the bottom which rolls over any type of surface. Optical mice with no moving parts require a special surface over which the mice are moved. While a mouse does speed up cursor movement (you may move the cursor quite rapidly across the screen, replacing the repetitive depressions of the cursor key), a mouse has limited applications for most computer use.

Light Pens

Another pointing device is a light pen. You hold the point of the pen close to the surface of the video screen displaying the menu selection you want. The pen circuitry detects the electron beam at that point illuminating the phosphor, which is then converted to coordinates usable by the CPU to indicate your choice.

Touch Screens

A touch screen is available, which has a system of lights and detectors surrounding the screen which form a network overlaying the screen. You point at the area of the screen which shows the menu item of interest. Your finger interrupts the light beams, which generates the coordinates at the location of interest.

Optical Scanners

A specialized data input device which is useful for certain applications is an optical scanner. One type of scanner reads bar code symbols and the other type reads special alpha-numeric characters. The bar code or the machine readable characters are read by a hand held device which is moved across the symbols. These input devices reduce the need to enter information into the computer manually, and reduce the chance of entering incorrect information. These devices are especially useful for inventory control applications, or servicing records for a large fleet.

Monitors

The most essential output device is a cathode ray tube (CRT) or monitor, which is essentially a television set without a tuner. The monitor displays each keystroke entered and the results of any information manipulation performed by the CPU. A monitor is an extremely useful output device for it allows you to examine immediately what you have entered on the keyboard. Mistakes can be corrected with minimal effort, and results are immediately available. The usefulness of the monitor is affected by the controller as much as it is by the monitor itself.

Types of Monitor

Monitors are included with some microcomputers but must be purchased separately from others. There are three major differences between monitors: the design of the monitor, the color or colors, and screen resolution.

Monitor design. Some computers have a monitor integrated with the computer and some have monitors connected to the computer by a cable. Some portable computers include a small built-in monitor. Monitors often have a pedestal with adjustments for height and angle.

Color. Monitors come with either monochrome or color displays. There are three types of monochrome (single color) monitors available: white on black, green on black, and amber on black. The color depends on the type of phosphor used in coating the inner surface of the cathode ray tube.

There are two types of color displays available: composite and RGB (red, green, blue). A composite monitor lacks the resolution of a RGB monitor due to the physical properties of the method used to generate the color. The composite monitor produces colors in the same way a home color television does, whereas a RGB display produces colors digitally. A RGB monitor, while it offers better resolution, is much more expensive than a comparable composite monitor.

Screen resolution. The screen resolution is the accuracy with which the screen can display an image. It is determined by the number of tiny dots, or pixels (picture elements) which make up the screen.

More pixels produce better resolution. Good resolution is particularly important for displaying graphics.

Selection Considerations

The major consideration in selecting a monitor is whether you want to display and produce graphics. Although there are other differences between monitors, these characteristics of the monitor have relatively little effect on the usefulness of the computer system. Three characteristics of the monitor which are worth considering are the flexibility, the color, and the ability to display graphics.

Flexibility. Monitors which are built into a computer may offer less flexibility than separate ones. The most important result is that the position of the monitor may not be adjusted for the user's comfort. The type of monitor provided may not meet the requirements of the agency; for example it may be the wrong color, too small, or not high enough resolution. Some portable computers with small screens for field work can be supplemented by a full size monitor for convenient office work.

Color. None of the three monochrome monitor colors, white, green, or amber, has been conclusively shown to be easier on the eyes than the others; European countries have approved the use of amber rather than green monitors on the basis of lower radiation emissions.

For most business applications, a monochrome display is entirely satisfactory. A color display is most useful for game applications and graphics; however it is only possible to print color graphics if you have a color printer. There are color printers on the market; for transit applications, their cost can probably not be justified. A color monitor graph will appear the same as a monochrome monitor graph on a black ink printer.

Graphics. If graphics will need to be displayed on the monitor, a resolution of at least 600 x 300 pixels is required. Most monitors offer this quality, however some do not. In addition, a special controller may be required to display graphics.

Monitor Controllers

The characteritics of the monitor are affected by the controller inside the computer, that determines the types of images that can be displayed on the screen. Some controllers limit the number of columns of characters to 40, although many programs produce 80 columns of information. These may be replaced by an alternative controller on an expansion board which will display 80 columns. A special controller may also be required to display graphics on the monitor, or to make color images on a color monitor. These controllers can be obtained on a color/graphics adapter board.

Other Displays

Other kinds of displays are used in very small computers when size is critical. One of these consists of liquid crystals, in which electric currents are selectively sent through small crystals to illuminate or darken them. Another type, electroluminescent display, is composed of a fine wire mesh where the intersection of two or more wires luminesces when current is passed through the two wires. The electroluminescent screen, while expensive, can display the same amount of information as can a large CRT, whereas the liquid crystal display is limited to a width of 20-40 characters and a length of 4-8 lines.

Printers

The output of the computer use is usually paper "hardcopy" produced by the printer. Since this output may be seen by many people and used in many ways its appearance is important. This factor, combined with the range of cost, reliability and print quality of printers makes printer selection one of the most confusing and time consuming parts of hardware selection.

Types of Printer

In some of the earliest microcomputer systems, it was not at all unusual to use a converted electric typewriter as a printer; however, this arrangement is not fast enough for daily operations requiring large amounts of output. The five major categories of printer used by today's microcomputers are: thermal, dot-matrix, daisy wheel, thimble, and ink jet. Two other types of printers, the electrostatic and laser printers are less commonly found and are not suitable for the transit operating environment. The thermal, electrostatic, and laser printers require specially impregnated paper.

Thermal. Inexpensive thermal printers are available with a number of computers. These printers use special heat sensitive paper to produce acceptable graphics and text. They are not versatile for printing different character types or line spacings. In addition the paper tends to darken with age or contact with certain chemicals such as tape adhesives. Their chief virtues are compactness and low purchase cost; however, they are inadequate for general applications.

Dot matrix. For day-to-day operations and in-house reports, a dot matrix printer is the conventional selection. Dot matrix printers can produce graphics and text, and are generally inexpensive and fast. Printing speeds in excess of 100 characters per second are not unusual.

The print quality of a dot matrix printer is not nearly as good as is the quality of other types of printer; you generally sacrifice quality for speed. Some more expensive dot matix printers do give what has been called correspondence quality print. In this print style, the print head actually makes two passes over the line to be printed. The first pass prints normally. For the second pass, the paper is advanced slightly for the second printing to fill in the gaps in the characters left from the first pass.

The dot matrix printing head consists of a bundle of pins held in a rectangular configuration. The more pins contained in this bundle, the higher the quality of print. The number of pins range from a minimum of 5 x 7 to a maximum of 36 x 50, with a 9 x 9 or 9 x 12 configuration being common. Characters are formed by selecting and raising the appropriate configuration of pins, which then strike the paper.

Daisy wheel and thimble. The daisy wheel and thimble printers are similar in that the daisy wheel or thimble have fully formed reversed characters on them. The print they produce is of comparable quality with that of a typewriter and they are referred to as "letter quality" printers. The daisy wheel or thimble are usually made of plastic; if your primary application is to produce large amounts of camera ready copy for reports, you may want to select a printer with metal wheels or thimbles. A metal wheel lasts longer than a plastic one, and leaves cleaner, crisper impressions. The daisy wheel and thimble printers have speeds in the range of 10-40 characters per second, slow when compared with the speed of a dot matrix printer but much faster than even the most skilled typists. These printers do not produce graphics.

Ink jet. The ink jet printer is by far the most expensive. Some ink jet printers have color printing capability. In general, the ink jet printer has a reservoir of ink (color printers have four ink reservoirs) and a set of nozzles arranged much like the arrangement of pins in a dot matrix printer. To form a character, selected nozzles are activated and ink droplets are sprayed from the nozzles to the paper. Keeping the nozzles clean is extremely important. The ink jet printer is very quiet in operation. Unlike the other printers, where an impression is made by physical contact between the paper and print head, the impression made by the ink jet printer is made only by the spray of ink hitting the paper.

Selection Considerations

The primary consideration in selecting a printer is the type of material which will be produced. If business correspondence and reports will be generated, good quality type is required, which can be provided by a daisy wheel or thimble printer. For printing graphics and compressed tables the necessary flexibility can only be provided by dot matrix or ink jet printers.

Some general considerations to keep in mind when selecting a printer are the carriage width, the capability of true proportional spacing, the paper feed mechanism, flexibility, and type of connection.

Carriage width. Most printers come with carriage widths of either 80 or 130 characters per line. Regular 8½ x 11 paper has an 80 character line. The wider printers use wide computer paper, and accommodate legal size paper turned sideways. The extra width is useful for producing large tables (such as budgets).

True proportional spacing. Some printers count the number of characters on each line and insert variable spaces in between the words and letters, so that the right hand margin is justified. This feature, available on some letter quality printers, gives a professionally type set appearance. Other printers right justify by inserting a constant size space in between words and letters. The variable, or true proportional spacing is not necessary for most purposes.

Paper feed. The paper feed mechanism can be either friction feed or tractor feed. Some printers provide both. Friction feed is what you find on typewriters. A single page is inserted by hand and paper is advanced by the friction between the carriage and rollers. Although friction feed can, in theory, accommodate continuous fan-fold paper, unless the continuous roll of paper is inserted with meticulous care, the paper will soon move out of alignment. Tractor feed uses pins on the carriage which are inserted in slots or holes on the edges of the paper. Tractor feed allows continuous feeding of paper and keeps the paper properly aligned, although it does require the use of special paper. Some printers have an optional automatic cut sheet dispenser which automatically feeds ordinary sheets of paper into the friction feed mechanism. This allows you to use ordinary typing paper, or your letter head, and is almost as fast as a tractor feed mechanism.

Flexibility. Dot matrix or ink jet printers provide a great deal of flexibility to the user. In addition to printing graphics, shadings, and so on, they can produce various different type, spacing, styles, etc. Most of them come with a menu of preprogrammed types such as bold face, italic, subscript, compressed or double width characters, etc. This is particularly useful when printing large tables or spreadsheets which can be shrunk using compressed print. Some of these printers also can print user defined type styles, or special character printing; the user writes or buys a program, telling the printer which pins or nozzles to use for a given character.

For most systems the flexibility provided by a dot-matrix printer is essential for producing graphics, or compressed tables. If letter quality print is required either a more expensive letter quality printer can be purchased, or a second inexpensive letter quality printer can be used. It is often preferable to buy a second printer which can provide back-up if one should breakdown.

Type of connection. The computer you have selected may determine the type of connection required between the printer and computer. The two most common connections between the microcomputer and printer are parallel or serial. A parallel connection passes eight bits of information at once, each bit carried on its own wire. A serial connection passes eight bits of information one at a time over a single wire; the first bit in the data is received first, the second bit is received second, and so on.

In general a parallel connection is preferable to a serial one, unless the computer and printer are more than 50 feet apart. Because the signals all travel down a single wire in a serial connection, various coordinating messages are required so that the receiving computer knows when each group of eight bits is starting, how fast they are coming, and so on. In a parallel connection, by contrast, each set of eight bits travel as a group, much less coordination is necessary and connecting the printer is simpler. If the cable must be more than 50 feet long the wires in the parallel cable interfere with each other; in this case a serial connection should be used.

Many computers come with a parallel or serial (asynchronous) data transmissions adapter or outlet where the printer can be plugged in. (These are discussed in Chapter 3.) If not, it is necessary to buy a controller board for the printer which provides both the controller and the outlet.

Some printers are incorporated in the same unit as the computer. For business applications of any sort, this is a bad idea. As the printer is a highly mechanical device, it is subject to failure more frequently than the other computer components. If the printer fails, and cannot be removed from the computer unit, you may lose your computer for the time it takes to repair the printer. The only reason it would be desirable to have an integrated printer is for system portability.

Plotters

A plotter is a peripheral device you may want to consider if your application makes intensive use of graphics. While graphing capability is available with most dot matrix printers, a plotter will allow for a choice of colors (by changing pens), is quicker for most applications, and results in neater, continuous line drawings. Graphics done on a plotter may range from line graphs, bar graphs and pie charts, to route maps.

There are two basic varieties of plotters: flat bed and drum. A flat bed plotter accepts single sheets of paper. Drawings are limited to the size of the plotter's flat bed drawing surface. Flat bed plotters are found with 9" x 12", 11" x 17", or larger drawing surfaces. A drum plotter uses continuous rolls of paper, so a drawing could conceivably be as long as the roll of paper, but is restricted in width.

Some plotters automatically change the color of pen in use. This is done under software control, that is, a command from the plotting program will instruct the plotter to change pens. Other plotters require a manual pen change.

The finer the resolution of the plotter, the smoother a curve or diagonal will appear. A diagonal line drawn with a plotter, upon close inspection, looks like stair steps. A fine resolution plotter draws a diagonal line in which the risers and treads of the stairs are very small. The more expensive plotters have a finer resolution, some capable of drawing line increments of .001".

CHAPTER 5

DATA STORAGE

The random access memory (RAM) inside the computer only retains information for as long as power remains uninterrupted. Without some form of permanent storage of the information contained in RAM, the program and data would have to be entered manually each time the computer was turned on. You could leave power on to the memory at all times, but with a number of different applications permanently stored in memory in this fashion, you would soon run out of RAM. Mass storage devices allow the permanent storage of programs and data, usually on some form of magnetic medium, even when the computer is turned off.

The four aspects of mass storage described in this chapter are:

1. Floppy disks
2. Hard disks
3. Tape storage
4. Controllers

The most usual forms of mass storage are portable floppy disks and fixed hard disks. Various types of magnetic tape are occasionally used for special purposes. Controllers may also need to be purchased for mass storage.

Floppy Disks

The dominant mass storage device is the floppy disk, a metal oxide coated disk which magnetically stores information. It is used with a disk drive, which writes information on, and reads it from, the disk. The process of reading from, and writing on a floppy disk is the same as used in tape recorders/players. A number of computer manufacturers integrate disk drives with the computer; the others make disk drives available as add-on components. Each computer has its own "standard" disk drive. When you select a computer, you usually select the kinds of disk drives it uses by default. It may be wise to look for a computer which uses a common size of disk, preferably compatible with one of the common formats. The main choice open to you is whether to have one floppy disk or two.

Number of Disk Drives

Computers with built-in disk drives include one drive as a standard configuration. Two disk drives, or one floppy disk and one hard disk drive, are strongly recommended for a number of applications. If only one disk drive is available, the user must constantly switch disks, which is annoying and time consuming. Having two disk drives is also useful in another way. The disk drive, like the printer, is a mechanical device. The disk drive spins the disk at a high speed. Because of this, the disk drive is much more subject to failure than are the other components on your computer. With only one disk drive available, if that one fails, your computer system will be virtually useless until the drive is repaired. With two disk drives, you can remove the malfunctioning drive for repair and still have one drive available for your applications.

Sizes of Disk Drives

Disks and disk drives come in a variety of sizes. There are 8 inch disks and drives, 5 1/4 inch disk and drives, and 3 1/2 inch disks and drives. Most computers use the 5 1/4 inch disks. Some of the new models have 3 1/2 inch disks, and the 8 inch disks are commonly associated with the dedicated word processors and larger mini-computers.

Disks of the same size used on different computers are not necessarily transferable. Computers with the same disk size and even the same operating system may write data on the disks differently, which prevents its being read by other computers. The "compatible" computers use a standard data format, making diskettes transferable between them.

Large disks do not necessarily hold more data than small ones. As described below, factors such as the density of information storage, and disk format, will affect the amount of information a disk can hold.

The 5 1/4 inch disk drives come in two different sizes: regular, which are about 2 1/2 inches tall, and "half-height," which are only about 1 1/4 inch high. The advantage of the half-height size is that you can have twice as many disk drives in the space that would be occupied by a regular disk drive. As the tolerances of half-height drive are extremely tight, they may be more subject to failure than will a regular drive.

Disk Capacity

The amount of information a single disk may hold depends on:

-the drive
-the operating system
-the disk itself

Double-sided (DS) drives write roughly twice as much information on a disk as the single-sided (SS) drives. A double-sided/double density (DS/DD) 5 1/4 inch disk may hold as much as 360k bytes of information. The 3 1/2 inch disk does not necessarily hold less information, because other factors may give the smaller disks a capacity of as much as 600k bytes.

The storage capacity of a disk also depends on the way the computer and operating system direct the drive to read from and write to the disk. The information on a disk is magnetically encoded onto concentric circles called tracks, with a gap left between each track. The smaller the gap, the greater the amount of information that can be contained on the disk.

A final variable affecting capacity is the way the disk is organized to receive information. Generally, the information is broken up into bundles, and each bundle is separately stored in a section of the disk known as a sector. Some disks have a rigid sized sector, and are known as hard-sectored disks. These sectors will generally hold 512 bytes each. If the bundle of information is smaller than 512 bytes, the remaining space in the sector is left blank. The other common method of storing information, soft sectors, allows sectors to vary in size. Thus, if the bundle of information contains only 400 bytes of information, the sector is sized accordingly. The total number of sectors on a given disk has a fixed upper limit, regardless of whether the disk is soft or hard-sectored. Thus, on a soft-sectored disk, while the computer manufacturer may claim a disk storage capacity of 360k bytes, you may only be able to use 300k bytes of storage if you have a number of short sectors on the disks.

Hard Disks

A useful mass storage device is the Winchester disk, also referred to as a fixed disk or hard disk. A fixed disk can hold very large amounts of data, and can read and write faster than a floppy disk drive. A fixed disk resembles a floppy disk drive, except that it contains permanently installed metal magnetic disks instead of removable plastic ones. The drive spins the disk at high speeds while reading and writing with magnetic heads.

A fixed disk drive is most useful for massive data storage applications. If data to be manipulated fills more than one one floppy disk at a time a hard disk is a good alternative. Programs can also be stored on a fixed disk, although some commercial software applications prevent you from copying the program to either a fixed or floppy disk.

Fixed disks are increasingly being included as an integrated part of microcomputers; however, there are differences between hard disks, and it may be worth considering a separate fixed disk in order to obtain features not found in the standard product. These characteristics include capacity, data back-up mechanisms, and data sharing.

Capacity

The fixed disk can from 15 to 200 times the amount of information that a floppy disk holds. Capacities range from 5 to over 70 megabytes (million, as opposed to thousand, bytes). The removable Winchester disks hold less information than the truly fixed disks, although they may hold up to 5 megabytes.

A rough estimate of the capacity needed for database applications can be made once the database applications have been identified. This number should be increased by a generous amount to leave space for unforeseen data requirements and programs.

Data Back-up

The data stored on the fixed disk is a valuable asset. It is usually accumulated over months and is updated frequently. If the fixed disk were to fail, and part or all of this data were lost, reconstructing it could be difficult and time consuming. This is particularly important when precise and auditable information, such as payroll or accounting records, are maintained on the disk. Although reconstructing maintenance records would be time consuming, their loss would be less disastrous. The data should be copied periodically onto some other form of mass storage, which can be used to reconstruct the lost data, if necessary. You could back-up the data on floppy disks, but to transfer 10 megabytes of data to floppy disks with 360k capacity would require several floppy disks and a lot of time.

Devices which will back-up fixed disk data at a reasonably fast speed include streaming tape, data cassettes, removable Winchester disks, and video cassettes. Major differences between them are speed, capacity, and cost. They are included with some hard disks, or can be purchased independently to back-up integrated hard disks. These media can also be used to store data which is no longer current.

Data Sharing

One advantage of storing data on a hard disk is that it may be shared by several users from different microcomputers. This is done by hooking the hard disk and both microcomputers together in a local area network. There are two reasons this may be desirable. First, the cost of the hard disk may be high enough that savings can be obtained by sharing that resource between several microcomputers rather than purchasing a separate hard disk for each machine. Second, in specific applications it may be necessary for two users to have access to the same up-to-date data on a continual basis; this can be accomplished by giving both access to a hard disk.

Tape Storage

Tape devices have been commonly used in the past to store information from computers, however their uses on microcomputers are limited. Various tape devices are used to receive information from the fixed disk and transmit information back to the fixed disk for back-up and archival purposes.

Cassette tape drives are used for mass storage on inexpensive home computers. The cassette tape drives are extremely slow and lack the storage capacity needed in a business environment.

Controllers

When adding a mass storage device to a computer system which formerly did not have one, you will need to purchase a device controller, which is a chip that receives signals from the CPU telling the device what to do. The device controller resides on a "board," an epoxy resin board with the device controller and associated circuitry and connections. The board is plugged into the data bus of the computer. Different device controllers are required to operate a fixed disk, floppy disk, or tape drive. Computer systems which come with one floppy disk already have a device controller. The device controller may control up to two or four floppy disk devices so you can add an additional disk drive without needing to purchase another device controller.

CHAPTER 6

OTHER EQUIPMENT

In addition to the basic components of a computer system (described in the preceding chapters), several components may be added to a computer for specific applications. The total number of additional components which you may successfully incorporate into your system depends on the components and the expandability of your computer. Some computers are not expandable at all and some limit the total number of additional components you may use. Additional enhancements that may be useful include:

- modems
- portable computers
- special data collection devices
- print buffers
- switches
- power protection
- networking

Modems

One peripheral device which is not essential but may be useful is a modem (modulator-demodulator). A modem allows one computer to communicate with another computer, transferring data or other information over telephone lines. The modem converts the sending computer's digital electrical impulses into acoustic impulses (modulates), sends those tonal signals over the phone line to the receiving computer's modem, which then demodulates the acoustic impulses into digital electrical impulses, usable by the receiving computer.

Types of Modem

Several varieties of modems are available. Some modems fit into a computer's expansion slot, whereas others are a separate device which connects with the computer through a serial port. The modems which fit into the computer itself are directly connected to the phone lines. The modems which must be plugged into a serial port may be either "direct" connected or "acoustic" coupled. The acoustic coupler modem has two cups over which the telephone handset is placed. The direct connect modems are becoming quite popular. They generally require less space and there is less chance of extraneous noise interfering with data transmissions. The acoustic coupler is a reliable modem and usually less expensive than a direct connect modem. For many years, the acoustic coupler modem was the only type available because of regulatory restrictions on what could be directly connected to phone lines.

Selection Considerations

Transmission speed. The most important consideration in selecting a modem is the transmission rate of information, measured in bauds (bits per second). The two most common transmission rates are 300 bauds and 1200 bauds. A 300 baud modem transmits a single spaced page of information in about 2 minutes, whereas a 1200 baud modem takes 30 seconds to transmit the same page. The most widely used standards in transmission are the Bell 103 for 300 baud transmission, and the Bell 212A for 1200 baud transmissions. These standards, or protocols, allow each computer to know what the other is doing. For example, the receiving computer must signal the originating computer that it is ready to receive information. If this is not done, information could easily be lost.

Full or half-duplex. Transmission can be one-way or two-way communications. A half-duplex modem only allows one direction of information flow at a time, whereas the full-duplex modem allows simultaneous bi-directional information transfer. Full-duplex allows the receiving computer to echo back data it receives; this can be compared to the original material to check for errors. Most modems are capable of both half-duplex and full-duplex.

Programmable features. Other features found on more expensive programmable modems are auto-dial and auto-answer. Auto dial eliminates the need for the user to manually dial the telephone to call up and connect with another computer. Without auto-dial, the user calls the computer and listens for the connect tone which the computer will send (or absence of connect tone if the other computer cannot accept a call). The user then connects the telephone to the modem, and the computers can then begin direct communication. With auto-dial, the phone line is first connected to the modem. The phone number (or numbers) of the computer you want to call is stored in memory. You merely tell your computer which number to call. If a connection is made, you may then begin data transmission.

To fully use an auto-answer modem, the user must provide a dedicated phone line for the computer and leave the computer and modem on at all times, both contributing to higher operating costs. If another computer user wants to access information from your computer, they call your computer directly and the connection is automatically made. Without auto-answer, the other user must first call you up, then you have to configure your system to send or receive information. The benefit of this approach is that you have total control over who is accessing your information. An auto-answer modem leaves your system vulnerable to unauthorized access.

Portable Computers

The truly portable microcomputers, also called lap computers or briefcase portables are not strictly part of the microcomputer system, but may provide a valuable complement to it. These portable microcomputers are ideally suited for certain applications in the transit environment, especially if they have a modem. Still smaller data collection devices, resembling hand-held calculators, may also be used for this purpose.

A lap size computer allows the collection of ridership or other data in the field. The data can be transmitted directly to your main office computer for analysis. This avoids having checkers filling out paper forms, then entering the information into the computer at a later date. The time and labor savings involved make it easier to collect more accurate and timely ridership information, and have it available for immediate use.

Special Data Collection Devices

Specialized data collection devices are available for various transit functions. Many of these are marked as part of a turnkey system for specialized applications, or are built into equipment for other purposes.

Automatic passenger counters (APC) and automated fare boxes contain memory which is used to store data for a limited amount of time. During the vehicle's operation, the APC or farebox records in memory the ridership or fare information for each trip and the clock time when they occured. The memory module can be briefly plugged into a microcomputer in the garage to dump or transfer all the data onto the computer. The memory is them erased and ready to record additional data.

Similar systems are available to record all fuel and fluids pumped in the service lane. A device installed in the line measures the fluid flow and sends the information to the computer. These devices can also prevent fuel use unless a recognized vehicle ID number has been entered.

These devices are currently available as part of comprehensive farebox service monitoring or APC systems. It is not feasible to purchase them separately except in very large operations where the scale might justify the design of a data collection system by technical experts.

Print Buffers

A print buffer is a peripheral device which permits the microcomputer to print output and be used for other tasks at the same time. The print buffer is a separate memory which stores information sent from your computer to the printer. When printing, the computer can send information at a much faster rate than the printer can use. Without a buffer, the computer must wait for the printer to print what it has, before the printer sends a signal to the CPU indicating that more information can be accepted. This process slows down the CPU considerably, and in some instances, you must wait for the entire document to be printed before doing anything else with the computer. A buffer will accept the information to be printed and then parcel it out to the printer, freeing the CPU to perform other tasks. You no longer need to wait for the printer to finish before you can use the computer for another task and there is no slowing down the tasks of the CPU.

Print buffers may be stand alone devices, that is, a separate component containing the memory or, if you have sufficient memory in your computer, you may use buffer software to set some of the RAM aside for this purpose. The program that converts a portion of computer memory into a buffer is called a print spooler. Several manufacturers of add-on memory or multifunction boards include a print spooler program with their product. The size of document which may be stored in a print buffer will be limited to the capacity of the buffer. One page of text requires approximately 2k bytes of memory capacity, so a 10-page document will need 20k bytes of buffer space. If your typical application results in a 15-page report, but you regularly produce a number of longer documents, then you may want to choose a buffer size capable of handling the longer document. On the other hand, if you only produce one long document a year, then you will probably be better served by a smaller buffer.

Switches

There are devices available which allow you to connect more than one computer to a single printer, modem or hard disk. Some of these are quite simple "t-switches," which allow two computers to share a single printer. Others are far more elaborate, allowing several machines to connect to a printer and incorporating a buffer.

The t-switch model allows only one computer to use the printer at any given time. To allow the second computer to use the printer, you must physically change the switch setting. This is the least expensive option.

The other devices allow each machine to output directly to a separate memory or buffer and the peripheral is effectively accessible to both computers simultaneously. Some of these devices also allow two peripherals to be connected, for example, a dot matrix printer for rough drafts and a daisy wheel printer for final reports. All switching is carried out under software control; no manual switching is ever necessary.

Power Protection

If a disruption in the electrical supply occurs while you are entering or manipulating information on your computer it may erase or damage data stored in random access memory. Electrical surges may damage some of the sensitive components of the computer. To protect against these variations in the electrical supply, which include total power outages, voltage drops, voltage peaks or surges, and random noise, a variety of line conditioners have been developed. These devices are plugged into your power supply and your computer is then plugged into the line conditioner.

Some of these devices protect against power surges and noise by filtering the electrical current before its reaches the computer. These prevent damage to the computer itself, but do not prevent possible loss of data or interruption of the program. More expensive devices include a battery as a back-up power supply. If current is interrupted for any reason, the device automatically switches to the back-up battery for power. This prevents a loss of information and also protects the computer. An inexpensive and relatively convenient option to prevent the loss of large amounts of work, is to frequently save the material by recording it on a mass storage device.

Networking

"Networking" refers to connecting several microcomputers so they can share information and peripherals. Networking may allow several small computers to share a printer, and a large capacity hard disk drive. The transit system data can be stored on the fixed disk, and each computer in the system may then directly access the data. Each computer can also share software stored on the disk, although abiding by licensing agreements associated with particular software packages may preclude the use of the software on more than one machine.

Function

In concept, the network is a large data and address bus with which the various microcomputers are connected. Each computer in the network has a board inserted in an expansion slot. The boards are connected by a coaxial cable. The peripherals (printer, disk drive, and so on) are connected to one of the microcomputers; other users access them through the microcomputer to which they are connected. Each computer user works with the CPU and RAM in a separate computer. The network program coordinates the use of the peripheral devices so that users are queued for access to the device. This prevents several users from accessing a file and manipulating it simultaneously. Some networks also provide security measures to prevent unauthorized users from opening files. Each network product has its own configuration and constraints, which affect its suitability for a particular system and its cost effectiveness.

The network must be compatible with the computers and operating system being used. The computers must be fast enough to be able to handle the extra load of managing the network.

Advantages and Disadvantages

Networks add considerably to the cost and complexity of the system, so it is important to explore the need for a network before proceeding. There are two main reasons for networking:

1. To provide more than one computer with immediate access to up-to-date data files. This might also be accomplished by transferring data directly between computers on a regular basis (using modems or

simply connecting the serial ports) or by swapping floppy diskettes of data. In special situations, such as booking demand-response trips from several computers, networking may provide all users with up-to-date information although they may not use it simultaneously.

2. To reduce the number of peripherals required by sharing them between computers. In some situations this could be equally well handled by using switches. The cost of providing additional peripherals should be weighed against the cost of the network or switches.

The primary danger with networking several microcomputers is that it may erode the speed of transactions. Several microcomputer users trying to access or store large amounts of data on a single disk drive may slow down the entire system. Sharing peripherals can result in a cost savings, but the additional cost of a network may eliminate those savings except in the smaller system where networking may not seriously reduce computational efficiency.

If your transit property is large enough that you intend to have several microcomputers and you are thinking of networking them, it may be worth considering a multi-user system. This type of system has a central computer, usually with 32 bit CPU chip, which is fast enough that it can serve a number of users. Each user communicates with the CPU through a terminal, which is essentially a keyboard and monitor. All computing is done by the centralized unit. This arrangement may be more cost effective than networking a number of 16 bit microcomputers.

APPENDIX A

GLOSSARY

Address bus. The path used by the CPU to identify locations in memory.

Application program. A program designed to perform a practical task, such as accounting, parts inventory, or route costing.

ASCII. American Standard Code for Information Interchange. A standard for representing the characters of the alphabet, numerical digits and punctuation in binary code (1s and 0s.)

Asynchronous port. Same as serial port.

Auto dial, Auto answer modem. A programmable modem which can store and dial telephone numbers or answer incoming calls without user involvement.

Backup. A copy of a program or data made for protection in case the original is damaged.

BASIC. Beginner's All-purpose Symbolic Instruction Code. An easy-to-learn, high-level programming language, much used on microcomputers.

Baud rate. Rate of data transfer over telephone lines in bits per second. Standard rates are 300 and 1200 baud.

BIOS. Basic Input Output System. Part of the operating system which controls input and output devices attached to the computer, including the keyboard, monitor, and printer.

Bit. Binary Digit. The smallest division of computer data, either 1 or 0.

Bit size. The number of bits processed as a group by a CPU microprocessor.

Board. A resin board holding chips and circuitry which enhances the computer's operation. Boards can be purchased as an option and plugged into one of the computer's expansion slots.

Boot. To turn on a computer and load the operating system into memory, preparing it for use.

Buffer. Memory used as temporary storage for data being transferred between the computer and a peripheral.

Bus. A path over which data travels between parts of a computer system.

Centronics. The standard connection for parallel communication.

Chip. A tiny integrated circuit etched on a silicon wafer. A chip can be a microprocessor or memory.

Clock speed. The speed at which a microprocessor operates, measured in megahertz or millions of cycles per second.

Command. An order to the computer to execute a task.

Command-driven. A program used by giving commands known by the user, rather than by selecting from a menu.

Compiler. Software which translates a program written in a high level language (source code) into binary object code understood by the CPU.

Controller. A microprocessor which coordinates a peripheral device (printer or monitor, for example) with the CPU.

Coprocessor. A microprocessor used to supplement the CPU by performing specialized tasks.

Copy protection. Techniques used by software distributors to prevent unauthorized copying or distribution of their programs.

CPU. Central Processing Unit. The microprocessor that does the actual computing and controls the flow of information in the computer.

CRT. Cathode Ray Tube. A video display monitor.

Cursor. A marker which moves around the monitor screen to show you where you are in the text or program.

Daisywheel printer. An impact printer using raised inverted letters at the end of the petals of a metal or plastic "daisy".

Database. A collection of information, organized for easy analysis and retrieval. May be a group of files.

Database manager. A program which allows the user to organize, build, and use a database.

Data transmission adapters. Devices which permit the computer to transmit data to and receive data from peripheral devices by using a predefined format.

Debugger. Software which helps a user to identify and correct program errors by following the detailed operation of the program.

DIF. Data Interchange Format. A standard format for data, permitting transfer of data between programs which use the DIF standard.

Disk, diskette, floppy disk. A plastic magnetic disk which is the most usual medium for recording and storing data.

Disk drive. A piece of equipment which reads data from and writes data on a disk as directed by a program and the CPU.

Documentation. The material which accompanies the program to teach the user how to use it and provide information for future reference.

Dot matrix printer. A printer which forms letters and images from rows and columns of tiny dots.

Erasable Programmable Read Only Memory. (EPROM) Memory which is not erased when the computer is turned off, and which can be programmed and erased by users.

Error trapping. A method for checking input to a program by comparing data with acceptable or unacceptable input values and rejecting unacceptable data with a message to the user.

Electroluminescent display. A display used on some portable computers in which characters are formed by wires which glow when current is passed through them.

Expansion slot. See slot.

File. A collection of data treated as one unit which can be a program, a piece of text, or statistical information.

File Manager. A program which allows the user to organize, build and use a file of data.

Fixed, hard, or Winchester disk. A permanently installed metal magnetic disk capable of holding large amounts of information, and rapid reading and writing of data.

Format. A pattern of subdividing a disk to organize the information written on it. Also a standard way of writing data so that it can be understood by a program.

Full-duplex modem. A modem permitting data to be transferred to and from it simultaneously.

Generic software. Programs which can be used as a multi-purpose tool, rather than having a specific application. Word processors, spreadsheets or database managers are common examples.

Half-duplex modem. A modem which can only transmit or receive data at a time.

Half-height. A compact design for disk drives, half the volume of the standard size.

Hard copy. Program output printed on paper, as opposed to that displayed on the monitor.

Hard disk. Fixed disk.

Hardware. The physical components of the computer, as opposed to the programs or software.

High level language. A computer language using English-like words, which must be translated by a compiler or interpreter before the CPU can understand it.

Ink jet printer. A printer which prints characters by shooting ink out of a grid of tiny nozzles.

Integrated programs. Programs which perform different functions but are designed to be used together as a package.

Interpreter. A program which translates a high-level language program into machine language step by step as it runs.

Kilobytes. (K) About 1000 bytes of memory.

Keyboard. A device resembling a typewriter keyboard used for input of information to the computer.

Letter quality printer. A printer which produces text of the same quality as an electric office typewriter.

Light pen. A device used to identify points on the monitor screen.

Liquid crystal. A type of display found in small computers where liquid is darkened by applying an electric field to it.

Local Area Network. (LAN) A system of hardware and programs for connecting microcomputers to each other and allowing them to share peripherals.

Megabyte. One million bytes, approximately.

Machine Language. The language made up of 0s and 1s is understood by the CPU.

Macro. A series of spreadsheet commands, stored and executed as a group.

Mass storage. Peripheral devices, such as disk drives, used to store data.

Menu. A list of options displayed by the program from which the user can select a command.

Menu-driven. Programs which are operated by the user selecting from menus of choices.

Microprocessor. A chip which performs computations or controls information flow, such as the CPU.

Modem. Modulator-Demodulator. A device which translates data from a computer's serial port into modulated signals to be sent over a telephone line and converts incoming signals back into a form understood by the computer.

Monochrome. A monitor which displays tones of a single color.

Mouse. A device which the user rolls across a desktop to move the cursor.

Monitor. The television-like display used for viewing computer output.

Multi-processor. A computer containing two microprocessors which can be selected as alternate CPUs.

Multi-tasking. A computer which can perform several tasks at one time by dividing CPU time between them.

Multi-user. A computer which can be used by several operators at a time from separate keyboard terminals.

Object code. The form of a compiled program in machine language which can be executed by the computer.

Off-the-shelf. Software which is widely commercially distributed and can be purchased at computer stores.

Operating system. A master program which allows the computer to run other programs by controlling flow of data between the CPU and peripherals.

Optical scanner. A device which reads special markings, such as bar codes, for direct input to the computer.

Network. See Local Area Network.

Package. A group of programs distributed as one product.

Parallel port. A port which transmits 8 bits of data, or a byte, simultaneously.

Peripherals. Devices which are plugged into the computer, such as disk drives and printers.

Pixel. A dot on a monitor display, many of which make up the image.

Port. An outlet through which the computer can communicate data.

Printer. A device which prints computer output on paper, creating hard copy.

Program. A collection of commands to the computer to be executed as a group.

Programmable read only memory. (PROM) Blank read only memory which can have a program written on it permanently.

Protocol. Standard conventions which allow two computers to coordinate communications.

Random access memory. (RAM) Internal memory on chips which is erased when the computer is turned off.

Read only memory. (ROM) Permanently programmed memory which holds programs installed by the computer manufacturer.

Resolution. The quality of image on a monitor display, affected by the size and number of dots or pixels on the display.

Record. A collection of information treated as a unit. A number of records make up a file.

RS-232-c. The standard for serial or asynchronous ports.

Sector. A portion of a diskette treated as one unit for reading and writing data.

Serial port. A port through which data is transmitted one bit at a time. Signals are used to indicate when each byte, or group of 8 bits, stops and starts.

Slot. An outlet on the bus for plugging in boards containing additional memory, controllers or other enhancements of the computer.

Software. Programs and languages used with a computer system.

Source code. The text of a program in a high-level language.

Spooler. A program which designates some portion of RAM to serve as buffer for temporary storage of material to be printed.

Spreadsheet. A program used to set up and manipulate large tables of information.

Surge protector. A device placed between the wall outlet and power cable of the microcomputer to protect the computer from damaging voltage surges.

System software. Software supporting application programs, including the operating system, programming languages and utilities.

Text editor. A program which allows the user to enter and change text stored in a file.

Text formatter. A program which allows the user to format text for printing by controlling margins, page length, indentation, and so on.

Thermal printer. A printer which forms images by heating points on heat sensitive paper.

Thimble printer. An impact printer which uses raised inverted letters on "thimble" shaped piece.

Track. A concentric circle on a disk used for defining and locating storage sections on a disk.

Tutorial. A simulated application of a program provided to introduce users to the program.

Utilities. Programs used to enhance the use of the computer and increase control and flexibility of computer use.

Winchester disk. Fixed disk.

Window. An area of the monitor screen used to display different applications or portions of the same application.

Word processor. A program for entering, editing, and formatting text documents.

APPENDIX B

REFERENCES

SOURCES OF INFORMATION ON MICROCOMPUTERS

UMTA

Three publications by UMTA are available from:

Microcomputer Reports
c/o Price Williams
962 Wayne Avenue, Suite 500
Silver Spring, MD 20910

Their titles are:

Selected Readings, Volume 1, Getting Started in Microcomputers

Selected Readings, Volume 2, Selecting a Single User System

Software and Source Book

Transit Industry Microcomputer Exchange (TIME)

The Transit Industry Microcomputer Exchange is a federal sponsored microcomputer users group. They publish a newsletter, "TIME Capsule," and distribute public domain software developed by other users. Their address is:

TIME Support Center
Rensselaer Polytechnic Institute
Civil Engineering Department
Troy, NY 12181
(518) 266-6227

National Cooperative Transit Research and Development Program (NCTRP)

An inventory of software on all computers at transit agencies is being conducted for NCTRP. For information on the status of this project contact:

Mr. Harry Smith
Projects Engineer
Transportation Research Board
2101 Constitution Avenue, N.W.
Washington, DC 20418
(202) 335-3224

Periodicals

Numerous periodicals are available which offer various perspectives on the microcomputer industry and uses. They are particularly helpful for comparative reviews of products which describe the use and attributes of the type of product. Reviews of specific products vary in usefulness, depending on the willingness of a particular periodical to honestly describe a product's shortcomings.

Some of these periodicals are obtained by most public libraries and they are widely available at newsstands.

General Magazines

Magazines which deal with the industry as a whole, without focusing on particular types of product are helpful for becoming familiar with the technology and its uses. Once a type of microcomputer has been selected they become less helpful, because material on other types of microcomputers may not be relevant.

Personal Computing is a readable general magazine which is helpful for its general discussions of computer uses and products. Monthly. $18/year.

Personal Computing
P.O. Box 2942
Boulder, CO 80322

Popular Computing is a readable general magazine which has useful overviews of product types and applications. Monthly. $15/year

Popular Computing
P.O. Box 307
Martinsville, NJ 08836

InfoWorld is a newsmagazine on the computer industry. Its descriptive no-holds-barred reviews of specific software and hardware products are particularly useful. Weekly. $31/year.

Info World
375 Cochituate Road
Framingham, MA 01701

BYTE is a thorough, more technically oriented magazine. It contains comprehensive discussions of product types and ways of using microcomputers. Monthly. $21/year.

BYTE
P.O. Box 590
Martinsville, NJ 08836

Product-Specific Magazines

If you have selected a particular type of microcomputer it is helpful to obtain one of the magazines specific to a microcomputer type. Because of their well-defined focus these offfer techniques and suggestions of immediate value in using the microcomputer and help the reader to understand and explore the range of abilities of the machine.

For the IBM PC and compatibles:

PC World. Monthly. $24/year (14 issues)

PC World
555 De Haro Street
San Francisco, CA 94107

PC Magazine. Bi-weekly. $34/year

PC Magazine
PC Communications Corp.
One Park Avenue
New York, NY 10016

For Apple microcomputers:

nibble. Monthly. $26.95/year

nibble
P.O. Box 325
Lincoln, MA 01773

Business Computer Magazines

A number of periodicals treat the use of computers within organizations. In addition to the technical aspects of automation these magazines discuss issues of management, personnel, and decision-making in relation to computers. Many of them include microcomputers as well as larger computer systems. Two of these are:

Business Computer Systems
270 St. Paul Street
Denver, CO 80206

Monthly, free to business personnel responsible for computers, $35/year for others

Computer Decisions
P.O. Box 1417
Riverton, NJ 08077

16 issues/year. Free to executives of organizations that use computers. $35/year for others

Software Reviews

An independent service which reviews software for the IBM PC is Software Digest Ratings Newsletter. Each monthly report covers one type of software, and rates programs on a variety of criteria. Monthly. $135/year.

Software Digest
One Wynnewood Road
Wynnewood, PA 19096

ARTICLES OF INTEREST

Annual Hardware Review, PCWorld, 1984. A summary of hardware products available for the IBM PC by type. Provides a good overview of the range and capabilities of products on the market.

Chapter 3: The Computer

PC World

"The (IBM) Compatibles Line Up.," by Robert Luhn, Vol. 2, No. 4, April 1984, p. 102. Discussion of compatibility and evaluation of IBM compatible machines.

Personal Computing

"Coprocessors: Mixing Apples and Oranges," by Paul Bonner, Vol. 8, No. 2, February 1984, p. 140.

Popular Computing

"IBM Compatibility," by Michael J. Miller and Tom McMillan, Vol. 3, No. 6, April 1984, p. 104.

"New Trends in Compatibility," by Michael J. Miller and Thomas Maremaa, Vol. 3, No. 6, April 1984, p. 112.

"Interfaces: Vital Links for Your Hardware," by Dara Pearlman, Vol. 2, No. 12, p. 170. Discusses parallel and serial connections.

Chapter 4: Communicating with the Computer

PC Magazine

"The Line on Bar Code Readers," by Dick Gall, Vol. 3, No. 12, June 26, 1984.

PC World

"Good Impressions", by Janette Martin and Stuart Schwartz, Vol. 2, No. 3, March 1984, p. 84. A discussion of letter quality printers and review of four examples.

"Silent Running," by Janette Martin, Vol. 1, No. 10, December 1983, p. 88. Description of ink jet printers.

"Pick of the Plotters," by Akshai K. Runchal, Jacob Treger, and Clement K. Tam, Vol. 2, No. 9, August 1984, p. 132. Evaluation of 3 plotters.

Personal Computing

"A Complete Buyer's Guide to Monitors," by Lynn Walker, Vol. 8, No. 6, June 1984, p. 162.

Popular Computing

"Monitors" by David Powell, Vol. 3, No. 4, February 1984, p. 122.

Chapter 5: Data Storage

PC World

"How Much Memory is Enough?," by Danny Goodman, Vol. 2, No. 6, June 1984, p. 62.

"Hard Disk Roundup," by Jonathan Sachs, Vol. 1, No. 6, September 1983, p. 98.

Personal Computing

"How Hard Disks Can Save you Times as Well as Space," by Robert Sehr, Vol. 8, No. 6, June 1984, p. 152.

Popular Computing

"A Complete Guide to the Disk," by Carlene Char, Vol. 2, No. 7, May 1983, p. 106.

Chapter 6: Other Equipment

PC World

"What Makes Modems Run" and "The Modem Market," by Larry Jordan, Vol. 1, No. 9, November 1983, pp. 54 and 88. What modems do, and what to look for.

"Local Area Networks," by Jonathan Sachs, Vol. 2, No. 7, July 1984, p. 69.

Personal Computing

"Connected! A Buyer's Guide to Modems," by Paul Bonner and James Keogh, Vol. 8, No. 4, April 1984, p. 146.

"A Buyer's Guide to IBM Expansion Cards," by Charles A. Miller, Vol. 8, No. 7, July 1984, p. 130. Includes a table comparing products.

"Modem Mistakes You Don't Have to Make," by David Gable, Vol. 8, No. 6, June 1984, p. 120.

Popular Computing

"Networking: What's In it for You," by Paul Bonner, Vol. 7, No. 10, October 1983, p. 128.

"Buyer's Guide to Modems," by David B. Powell, Vol. 3, No. 9, July 1984.