*GUIDELINES FOR SELECTION OF MICROCOMPUTER HARDWARE**

By

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Guidelines For Selection Of Microcomputer Hardware

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Eric W. Crawford, Carl K. Eicher, and Carl Liedholm,
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PREFACE

There is a worldwide revolution in small computer technology underway and scientists are struggling to find ways to utilize this new technology to help solve development problems in the Third World. We are pleased to announce a number of papers on microcomputers in international agriculture will be published in our International Development Papers series. The aim of these papers is to provide timely information about the rapidly changing state of the new micro-processing technology and its use in research. The papers are also intended as guides to agricultural and social scientists on choosing, installing, and maintaining microcomputer hardware and software systems in developing countries.

Some of the papers will also document field experiences of selected established projects using new data processing hardware and software. Other papers will concentrate on developing guidelines for establishing and maintaining successful microcomputer and/or programmable calculator installations for agricultural research in developing countries.

The present paper is the seventh of these new papers. It is based on work by faculty, staff, and graduate students of the Department of Agricultural Economics, Michigan State University, on cost-effective data collection, management, and analysis techniques for developing country applications. This activity is carried out under the terms of reference of the Alternative Rural Development Strategies Cooperative Agreement-- DAN-1190-A-00-2069-00--between the Office of Multi-Sectoral Development, Bureau of Science and Technology of the United States Agency for International Development and the Department of Agricultural Economics at Michigan State University.

The author of this paper, Chris Wolf, is the manager of the Agricultural Economics Computer Service at Michigan State University. He has worked on many computer-based simulation and data analysis projects, several involvng data collection in developing countries. He has also assisted faculty and students in selecting microcomputer hardware and software and in exploring the capabilities of this equipment in research activities.

Readers are encouraged to submit comments about these new papers on microcomputers and to inform us of their activities in this area. Write directly to: Dr. Michael T. Weber, Acting Director, Alternative Rural Development Strategies Cooperative Agreement, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan 48824-1039.

Eric W. Crawford, Carl K. Eicher, and Carl Liedholm
Co-Editors
MSU International Development Papers

INTRODUCTION

The recent availability of moderately priced, yet powerful, microcomputers has aroused the interest of almost everyone who spends a significant amount of time working with numbers or words. These machines show great promise as a tool for scientists, engineers, researchers, and managers. As a result, there are many people with little or no prior computer experience who are trying to decide if a microcomputer can help them and, if so, which one to buy.

There are many good reasons for buying a microcomputer and there are also many bad reasons. For some projects, it may be more appropriate to use a large, high-speed computer; for others, typewriters and pocket calculators might be the best choice. Introduction of a microcomputer into a setting where it is inappropriate can waste a lot of money and time. Entire books have been written to help potential buyers decide whether a microcomputer is the appropriate tool for their needs. The last section of this document suggests additional readings covering this and other microcomputer topics. It is assumed here that you have already made the decision to buy a microcomputer and are looking for guidance in the selection of one.

This document is aimed primarily at researchers in developing countries who have little experience with computers and limited access to information about microcomputer hardware. For that reason it is written at a fairly basic level yet it tries to cover a lot of material. It is intended as an introduction to the various components and features of microcomputers, not as a comparison of different brands. It does not make any specific brand-name recommendations. There is no single "best" microcomputer and even if there were, new machines are being introduced so fast that that would change every few months. In addition, there are too many variables (including local availability and service, compatibility with equipment used by one's colleagues, etc.) for someone in Michigan to recommend a particular brand of computer as the best choice for everyone reading this paper.

There is such a wide variety of computing equipment available today that it is necessary to limit this paper to a specific subset of the microcomputer market. So-called "home computers" or "game computers" do not have the capacity, flexibility, or durability to serve the needs of an administrator or researcher, so they are not considered here. "Micro-mainframes" and multi-user systems usually cost upwards of $10,000, putting them beyond most development project budgets, so they are also excluded. The kind of system that is considered here can be characterized as a typical small-business or professional computer. It has at least 64K bytes of memory and two disk drives. It has a screen capable of displaying 24 lines of 80 characters and a full-size, typewriter-style keyboard. It has a printer that prints lines of at least 80 characters. It is a single-user system, with no capability for adding more terminals. If you are looking for something significantly more or less than this, then you should look elsewhere for information, although some of the more general advice that follows might be useful to you. If the description above did not mean much to you or you don't know what you want, then this paper should be a good starting place.

Two caveats are in order regarding the content of this paper. First, some recommendations are made regarding desirable features and capacities. These represent the author's opinions and, as such, are subject to reasonable disagreement. Second, the microcomputer market is changing so rapidly that written material on it tends to become out-of-date quickly. This paper covers the market as it is in October, 1983.

Microcomputer Components

A microcomputer system consists of a number of parts that interconnect to make a working computer. This "component" aspect of microcomputers will quickly become obvious to you when you start reading about them or talking to people about them. You will start hearing about serial ports, CPU chips, printer interfaces, RGB monitors, memory boards, and RS232 cables. The remainder of this paper will attempt to explain what the different parts are and how they are important in your choice of a computer.

When microcomputers first became available in the mid-1970's, the companies that manufactured them tended to be very specialized and the people who bought them were generally technically-inclined people who looked upon the computer as a hobby. They would buy a processor board from one company, memory chips from another, a couple of serial interfaces from a third, a keyboard from a fourth, and use an old TV set for a display. Relatively few people are capable of doing this sort of thing and fortunately there is no longer any need to. All of today's popular microcomputers are available as completely assembled, ready-to-plug-in systems.

There is still reason for you to understand the basic components of a microcomputer system, because the characteristics of the components may make one computer more suitable for your work than another. Even with today's "packaged" systems you have some freedom to choose individual components from other manufacturers to tailor the system to your needs or to save money. In addition, understanding what each piece of hardware does can make you better able to cope with a sales pitch that touts one machine as better than the rest because of some particular technical feature.

Selection of a microcomputer is a nontrivial task with many different ways to go wrong. The bulk of this document contains technical information that will help to prepare you for the task. Before we get to that, there is some more general advice, in the form of do's and don't's, regarding how to shop for a microcomputer.

DO'S AND DON'T'S IN SELECTING A MICROCOMPUTER

1. Know What You Want To Use It For

All computers are capable of a wide variety of tasks, but each machine has different strengths and weaknesses. You can only make a wise choice of a computer if you know exactly what tasks you want it to do. If you buy a computer with the vague idea of "automating our records" or "helping in our research", it is quite likely that you will make a mistake. You may simply spend too much money buying a machine or software whose capabilities you will never use. If you are unlucky, you will wind up with hardware or software that won't even do what you bought it to do.

The more specific you can be about your needs, the better choice you are likely to make. If you are going to do word processing, you will need a machine that displays at least 80 characters on each line of the screen. If you are going to exchange data or programs with a colleague you will need to have compatible computers. If you are going to do extensive numeric data entry you will need a keyboard with a numeric keypad. If you are going to analyze highly-aggregated data such as annual national production data for 10 commodities for 20 years disk drives of 100K byte capacity will be large enough; for a year of daily survey data from 200 farms you will need considerably larger disks.

While you are doing this kind of thinking, plan for the future as well. How might you expect your needs to change in the future? You will probably be better off buying a machine that has more capacity than you need, rather than one whose limits you will reach the first day you use it.

2. Don't Make a Hasty Decision

The process of choosing a computer should not be a quick one. You should probably spend a minimum of two months talking to people, visiting stores, and reading books and magazines before you make a decision. Doing this will not only give you a better idea of the market but should also make you aware of many possible uses of computers that you had not thought of. As a result it should enable you to better specify what you will do with one.

On the other hand, don't think you have to become an electrical engineer in order to make a wise decision. After a certain point, gathering more information is not going to be helpful, so don't be compulsive about your research.

3. Don't Wait for Tomorrow's Technology

It is well known that microcomputer technology is advancing rapidly, and many people take this to mean that they shouldn't buy a computer now. These people are usually afraid of one of two things: 1) that their newly-purchased computer will immediately be obsolete, or 2) that prices are going to drop dramatically.

If you have a use for a computer now, there is no reason to wait. There are many highly capable computer systems available at reasonable prices today. If you find one that meets or exceeds your needs now, it should remain useful for at least five years. It may be technologically obsolete, but as long as it is doing a job that you need done it is not functionally obsolete. Trying to stay technologically up-to-date can be a very unproductive and even costly endeavor.

Rumors of new computer systems and even announcements of them can precede shipments to dealers by as much as a year and the rumors often promise more than is delivered. New systems of hardware are notoriously unreliable and there is rarely much software for them. A time-tested and proven system is by far the better choice for most users.

4. Talk To Other Microcomputer Users...

Other microcomputer users can be a valuable information source in some ways because they may have recently gone through the process of selecting a computer. Others in your area may be particularly useful for information about the reliability of local dealers or the intricacies of customs regulations. Others who are doing research similar to yours may help you identify hardware or software that works particularly well or particularly poorly for that application. Most computer owners are eager to show off their computers and talk about their frustrations.

Be sure to talk to the people who are actually using the computer, because they are likely to know more about the day-to-day successes and failures than will a project leader. In addition, an administrator may attempt to make a project appear more successful than it actually is.

One particularly good source of information is a local computer users' group. You may find one composed of people owning many different brands of computers or you may find a group that specializes in a particular brand. Either one could be quite helpful. If you have a lot of trouble finding other computer users, a local dealer may be able to recommend some of his customers for you to contact.

5. But Don't Believe Everything They Tell You

Unfortunately the quality of the information you get from different people will vary widely, because of their differing fields of training, depth and breadth of experience with computers, and personalities. In fact, unless you are extremely lucky, some of the advice you get will be dead wrong and therefore worse than no advice at all. There is no reliable way for you to tell whom you can believe and whom you cannot. Some of the people who sound the most knowledgable or trustworthy may not be. The following are three kinds of "misinformers" to watch out for.

a. The One-Computer User

This person typically has a non-technical background, but has acquired a microcomputer and learned how to use it for one or more applications. This person is definitely lacking in breadth of experience (from having used only one computer and a few software packages) and is often lacking in depth as well (from having pursued a particular application only as far as his individual needs). The major error this person makes is to extrapolate his experiences to other situations where they don't apply. Microcomputers have incredibly varied capabilities and methods of use. This person doesn't have the experience to know this yet.

b. The Technical Expert

This person usually has a background in engineering or computers, and tends to speak in nothing but computer jargon. Obviously computers are a technical subject which at times requires technical language, but the people you talk to should recognize you as a novice and adjust their language accordingly. If they don't, it may mean they are only interested in the technology of computers, making their advice about practical applications of computers highly suspect. On the other hand it might mean they are using techno-jargon because they don't understand the subject well enough to explain it clearly.

c. The Absolutist

Be extremely suspicious of anyone who tends to speak in absolute pronouncements without explanations or qualifications. This also applies to the person who has an answer for every question, who never says "I don't know" or "I'm not sure". These people can be the most insidious because they may sound incredibly knowledgable. Unfortunately it is almost always too good to be true. There are very few simple answers when it comes to computers.

You may get misinformation anywhere - from a salesman at the computer store or from a trusted friend. Your only protection is to be skeptical and ask lots of questions. And most important, don't make any important decision based on information you've heard from a single source (including this document).

6. Plan Your Purchase To Include Software

There are two aspects to this. The first is one of budgeting your purchase. It is easy to look at microcomputer prices today and think that you can get a complete computer system for as little as $2500. However, in most cases, this will not include software. You will quickly find your microcomputer to be an expensive paperweight if you don't have the software to make it a useful tool. You may also find it difficult to get money allocated later to buy software. A financial officer may not understand why, when you just bought a $4000 computer, you need to spend another $1000 for a few programs. This is why you should consider the hardware and the software as a system and should allow $500 to $2000 for initial software purchases.

The second reason you should consider software is compatibility. There may be a software package that does exactly the job you need, but if it doesn't run on your computer, you're out of luck. Many experts advise that you should first decide what software you want and then buy a machine that will run it. This is excellent advice for most people in the U.S., who have access to such a wide variety of computers, but may not apply to those overseas who may have more limited choices. It is important though, and the availability of appropriate software should be considered when choosing a machine. Note that this is strongly related to the first point above - knowing what you want to use the machine for.

7. Make Sure You Have The Personnel To Use It

A computer requires people to run it; it will not be productive sitting in a corner unused. In order to get the most out of your computer, you should have one or more people responsible for learning how to use it and becoming expert enough to be able to teach others. Learning to use a computer is usually not an easy task for a novice. This is particularly true when the only instruction available comes from computer manuals. There is no simple way to determine who is the best person for this responsibility. It might be a researcher, an administrator, a clerk, or a technician. It should certainly be someone who shows an interest and curiosity about computers. Someone without the necessary curiosity will probably not explore enough to really uncover the machine's capabilities and intricacies. It should also be someone who has a reasonably methodical and logical manner of approaching problems. You should ultimately attempt to develop computer expertise in several staff members, to maintain some continuity if one person leaves.

8. Don't Expect Immediate Results

Some computer ads give the impression that you can expect to unpack your microcomputer, plug it in, and have all your problems solved that afternoon. For some simple applications this might be true, but don't count on it. For any task of moderate complexity, there are bound to be unforeseen problems. If you have a project that is approaching a deadline, trying to complete it by buying a new computer will probably put you further behind schedule. If you are implementng a crucial application like payroll it would be foolish not to run the old and new systems simultaneously for several months to guard against failures. This of course will take longer to run than the old system alone. A secretary may take longer and make more errors using a new word processing package than using a typewriter. The real payoff in computerized systems may not come for three to six months after you first use the system. If you are expecting immediate results you may be very disappointed.

BITS AND BYTES

Computers are basically information processors. Since one of the ways they differ from each other is in the amount of information they can process or store, we must have some way of quantifying information in order to make useful comparisons between them.

The simplest unit of information is a binary digit or bit. It is called binary because it can have one of two possible values - zero or one. It can be thought of as a switch that can only be on or off.

A bit is really too small to be very useful. In addition, if a computer had to process each bit separately, one at a time, it would be very, very slow. Instead, computers group them together into strings of 8 bits, which are known as bytes. If bits are expressed as 0's and 1's, a byte might look like 10100010 or 00101110. There are 2^8 or 256 possible combinations of 8 bits, so a byte can have 256 possible values.

When a computer processes textual (as opposed to numeric) information each 8-bit combination of 0's and 1's represents a particular character (01000001 is an A, for example). For this reason bytes are often equated with characters when storage capacities are expressed. For most purposes an integer (or whole) number will require two bytes of storage and a real number (one with decimal places) will require four bytes. This means that 1000 bytes of memory could hold 1000 characters, 500 integer numbers, or 250 real numbers.

Since a byte is still a pretty small unit of information, any computer of a reasonable size has capacities measured in thousands or even millions of bytes. To avoid the need for so many multidigit numbers, a shorter form of notation is commonly used. In the same way that large budgets are expressed in thousands of dollars or millions of francs, microcomputer capacities are measured in kilobytes (Kbytes) and megabytes (Mbytes).

This sounds straightforward enough, but there is one complication that often confuses people. From standard metric terminology you would expect 1K byte to be 1000 bytes. That's close, but not quite right. On computers, quantities are almost always measured in powers of 2 and 2^{10} just happens to be 1024. Since this is so close to 1000 the prefix kilo was adopted to represent 1024 units of something. As a result 64K bytes is actually 64*1024 or 65,536 bytes. Likewise a megabyte is 1024*1024 or 1,048,576 bytes.

Unfortunately you will sometimes run across references to Kbytes or Mbytes that do not use the standard computer definitions. Usually it makes very little difference, but it can cause confusion. Occasionally, you may see articles in the popular press about a computer with "over 65K bytes of memory". You should recognize that this is a 64K byte computer described with faulty terminology.

The designation "bytes" is often omitted, so you will see specifications like "140K disk capacity". In references to total memory size or disk capacity, bytes are always the implied units of measurement. However, in references to individual chip capacities the units used are always bits. For example, you may have heard that most manufacturers are now using memory chips with a capacity of 64K. This is 64K bits, or 8K bytes, so a computer with 64K bytes of memory will require eight of these chips, not one.

MICROPROCESSORS

Most people tend to think of a computer as something that does a lot of arithmetic very quickly. In fact, the microprocessor which is the brain of a microcomputer is really a general-purpose information handler that can follow instructions very precisely and very quickly. The instructions it is given can make it do arithmetic, process words, or control an assembly line. When electronic designers got a look at the first microprocessors they all saw them as the answer to different needs. In fact, most microprocessors have not gone into computers; they have gone into video games, microwave ovens, cars, cassette decks, lab instruments, etc. This versatility led to great demand for microprocessors which resulted in large-scale production followed by the design of new, more powerful processors. This led to further applications, larger production, and more development. As a result, the microprocessor that goes in your computer today is one of the least expensive parts, costing perhaps $5 to $50.

Characteristics

The microprocessor is an integrated circuit or "chip", so-called because it is a rectangular piece of black plastic about 20 mm wide and 60 mm long. Externally it is indistinguishable from the many other chips in a computer, except that it is usually the largest one.

A microprocessor by itself cannot do much in the way of useful tasks. It needs to be connected to other chips that allow it to store instructions, accept input signals in some form and to produce output signals in an orderly way. A circuit like this can be put together on a printed circuit (PC) board made of epoxy about 1 mm thick and perhaps 100 mm wide by 200 mm long. It could sell for one or two hundred dollars. This in itself can be called a microcomputer, because it performs all the basic functions of a computer. It could be plugged into some other device, a microwave oven for example, where it could respond to the push of different buttons, the timing signal from a clock, and the information from a temperature probe to control the operation of the oven.

To be able to work as a general-purpose computer, it must be able to do much more, accepting letters and numbers as input, responding to special keys in particular ways, displaying information in a way we can understand, storing information for use later, etc. To achieve this, the microcomputer must be built into a microcomputer system, which adds a great deal to the size and cost. The board described above, containing the microprocessor, will be inside the computer system and is referred to by many different names including motherboard, processor board, system board, and CPU (central processing unit) board.

The term microcomputer is very often used to refer not just to the board but to a microcomputer system, including the keyboard, monitor, disk drives, etc. Because this usage is so common and convenient, it will be adopted for this paper as well.

Microprocessor Families

There are probably hundreds of different microprocessors available today but only about a dozen of these are used in general-purpose microcomputers. Microprocessors are generally designated by model numbers, and it will help you to be somewhat familiar with these.

Microprocessors can be grouped into families, which are distinguished from each other by their instruction sets. An instruction set is the set of commands that a processor will respond to. This does not refer to the commands that you can type in from the keyboard or to BASIC language statements, but rather to the code numbers that pass as signals through the internal wiring of the machine telling the processor in minute detail what to do next. This is usually referred to as "machine language", since it is not in any way similar to human language in the way that BASIC is. Since all microprocessor instructions are essentially numbers, the instruction sets are really defined not by the numbers themselves, but by how the microprocessor is supposed to respond to them. Two different processors will both have an instruction 15, for example, but that 15 may tell one of them to go to a new location and execute another instruction while it may tell the other processor to add two numbers together. Those microprocessors that are designed to respond in the same way to most of the commands they receive are said to belong to the same family.

The three most common microprocessor families are the 6800, 8080, and 8086 families. Each of these takes its name from one of the processors in its family. The 6800 family also contains the 6502, 6509, 6510, and 6809. These processors are used in Apple, Commodore, and Atari computers. The 8080 family also includes the 8085 and Z80 chips. This is the most commonly used family of processors, appearing in machines from Radio Shack, Osborne, Zenith, and in all other CP/M-80-based computers. The 8086 family includes the 8088, 80186, and 80286 (and is easy to confuse with the 8080 family). The most prominent machine which uses this chip is the IBM Personal Computer, but there are many others.

There are several other, less common, microprocessors you may encounter, including the 16032, 68000, and Z8000. The 68000 is probably the most important of these for the future because, although it is expensive right now, it is extremely powerful. It is used in Apple's Lisa and Radio Shack's Model 16, which are both top-of-the-line computers.

8-bit Vs. 16-bit

One of the significant characteristics of a microprocessor is the amount of information, measured in bits, that it can process at one time. The very first microprocessors were 4-bit processors, but those are no longer used in computers. Almost all the machines on the market today use either 8-bit or 16-bit processors. 32-bit microprocessors are becoming available, but they are only used in relatively expensive microcomputers at the moment.

The two most common families of microprocessors, the 6800 and 8080 families, consist of 8-bit chips. The 8086, 68000, and Z8000 are all 16-bit processors.

The situation is slightly more complicated than this, however, because some processors have two different "sizes", one that tells how they communicate with other chips and one that tells how much they process internally. The 8088, a member of the 8086 family, might be described as an 8/16-bit processor because it can only accept or transmit 8 bits at a time but it can put together two sets of 8 bits internally and then manipulate all 16 at once. Thus the IBM PC, which uses the 8088, is not a "true" 16-bit machine although it is often described that way. To make this more confusing, the other members of the 8086 family are true 16-bit processors. Under this terminology, the 68000 would be a 16/32-bit processor.

There are two main differences between 8-bit and 16-bit processors. 16-bit processors are generally faster than 8-bit processors, because they can do more in a single operation. However when considering speed it's important to remember the distinction between a microprocessor and a microcomputer system. The microcomputer system has many parts, the microprocessor being only one of them. The speed at which the computer can do a particular job may be influenced far more by the circuit design (the way the microprocessor is connected to other chips), the disk drive speed, the video display circuitry, or other factors. As a result two machines which use the same microprocessor can vary widely in how fast they execute the same program. In addition, programming techniques can have a major influence on speed. Two database packages of similar capabilities running on the same computer can differ tremendously in speed.

The fact is that a 16-bit computer will not necessarily run faster than an 8-bit computer, even though some sales people and advertisements will lead you to think so. A very general rule of thumb is that machines using 6502, Z80, and 8088 chips will be similar in speed, while those using a 68000, 8086, 80186, or 80286 will be faster, assuming everything else is equal (which, of course, it almost never is).

The other main difference between 8-bit and 16-bit processors is in the amount of memory they can use (or "address"). 8-bit microprocessors can directly address up to 64K bytes of memory. 16-bit microprocessors can address up to 1M byte of memory (16 times as much) or more. For some applications, the difference in memory size between an 8-bit and a 16-bit machine is very significant, far more significant than the difference in speed. This may be the major reason that you consider buying a 16-bit computer. This subject is discussed further in the section on memory.

Clock Frequency

Every microcomputer has an internal "clock" which generates regularly spaced pulses that control the timing of the microprocessor's operations. The frequency of these pulses determines how fast the microprocessor runs, with a higher frequency producing faster operation. The clock frequency (sometimes referred to as clock speed) is measured in megaHertz (MHz). Its value is typically between 1 MHz and 10 MHz.

It would seem that manufacturers would want to use extremely high clock frequencies to make their computers faster. Unfortunately there are limits on how fast a microprocessor, a memory chip, or other chips can run. If the clock is speeded up too fast, one chip may not be able to "answer" another one before the second one has gone on to another operation. Signals will get read incorrectly and general chaos will ensue. As you might expect, chips that will run at the highest speeds cost more than equivalent ones that are not as fast. The manufacturer has to choose between economy and speed.

Some manufacturers who use high frequency clocks in their machines promote this in their advertising as a big advantage. During certain operations graphics for example, the extra speed may be quite noticeable, but it is important to remember that in day-to-day use of the machine the speed of your printer or your disk drives may have far more influence on the overall speed of the system.

Operating Systems

Since the different microprocessor families have different instruction sets, any program written in machine language (as opposed to a higher-level language like BASIC or Pascal) will run only on machines that have the corresponding processor. Since almost all operating systems are written in machine language, the processor in your computer will determine what operating system you can use. The three most common operating systems that run on different brands of computers (as long as they contain a microprocessor from the right family), are CP/M-80 (formerly known simply as CP/M), MSDOS (also known as PCDOS or IBM DOS), and CP/M-86. CP/M-80 runs on chips from the 8080 family while MSDOS and CP/M-86 run on chips from the 8086 family. Interestingly, there is no similar "standard" operating system for the 6800 family, i.e. one operating system that will run on Apple, Atari, and Commodore computers.

Multi-Processor Machines

There is one more twist to the subject of microprocessors - it is possible for a microcomputer to have more than one microprocessor. There are some computers that are designed that way; their standard versions come with two processors. Two examples of this are the DEC

Rainbow, which has a Z80 and an 8088, and the Zenith Z-100, which has an 8085 and an 8088. These machines come with both CP/M-80 and MSDOS operating systems. The Radio Shack Model 16 has a Z80 and a 68000 and can run both CP/M-80 and XENIX (another 16-bit operating system).

It is also possible to add a second CPU board (containing a second microprocessor) to a computer that was designed with only one. Probably the most popular adaption of this type is to add a board with a Z80 to an Apple II computer. The CP/M-80 operating system requires a chip from the 8080 family, thus a stock Apple (which uses the 6502) cannot run CP/M-80. The addition of the Z80 board enables the Apple to run a great deal of CP/M-80 software that it otherwise could not. There are Z80 boards available for many other machines, and 8088 and 8086 boards are on the market as well.

When using a machine with more than one processor, the user generally does not have to do anything special to tell it which one to use. On an Apple, for example, if you start the computer up with a regular Apple disk, the Z80 board will be idle and the computer will act like an unmodified Apple. If you start it up with a CP/M-80 disk, the Z80 board takes over automatically. Some machines with two processors even take advantage of the inactive one, using it for some "housekeeping" chores that the main processor would have to do otherwise.

BUSSES AND SLOTS

As described earlier, a CPU board must be connected to other components (often called peripherals) to make a working computer system. These other components include memory chips, disk drives, a display screen, and a printer, as well as many others. The designer must decide how to connect these devices, taking into account the conflicting goals of low cost and flexibility.

The most straightforward way to connect the additional components is to run wires from each of them directly to the CPU board. This can be done using a set of multi-wire cables, one for each peripheral device, which are attached (by soldering or with plug-in connectors) to the apprropriate boards. The cable connecting to the memory board would carry all of the signals related to memory access, the cable to the disk drive would carry disk-related signals, etc. If the disk drive cable and the memory board cable were mistakenly interchanged, the computer would not function at all because the components would be receiving the wrong signals.

The other way to connect the components is by using a system bus, a collection of <u>all</u> the signal lines that are needed to connect <u>any</u> two components. The bus will usually consist of 50 to 100 different signals. These signals are made available to the components through a set of 5 to 10 "slots" (sometimes called expansion slots) into which printed circuit boards can be inserted. The slots have electrical connectors for each of the signals on the bus, and the circuit boards have matching connectors that make electrical contact when the board is plugged into the slot. Each board is designed to use only those signals that are relevant to it, ignoring all the others. In most bus designs, all of the slots are electrically equivalent, so any board can be inserted in any slot (one prominent exeception to this is the Apple II). If the board is controlling another componet (e.g., a disk controller driving a disk drive or a video board driving a display screen), that component will be connected to the board with a cable specific to its application, independent of the bus.

The major advantage of a bus design is its flexibility. It allows each user to connect those components needed in his system. One user might connect disk drives, a color monitor, two printers, and a plotter. Another might have disk drives, a monochrome monitor, a printer, an extra memory board, and a modem. A bus design also allows a computer to be updated by replacing old components with new ones. It even allows other manufacturers to design components for the computer, providing the user with more choices than the computer manufacturer alone could provide.

The electrical wiring in your house is a simple example of a bus design. The "bus" consists of three "signals", carried on a hot wire, a neutral wire, and a ground wire. The wall outlets are the slots and your electrical appliances are the components. The characteristics of the "signals" and of the physical plug are well known, so that any manufacturer can make devices that will work properly with them. You can buy thousands of different electrical devices, all designed for this "bus". You know that you can plug in your vaccuum cleaner in any room and it will operate. Imagine what it would be like if all of your electrical appliances had to be wired into your house at the time it was built and any additional ones had different voltage needs, requiring major electrical work to install a new TV set! The beauty of a bus design should be obvious.

A bus design does cost a little more to manufacture, because of the cost of the connectors, and it makes the computer a little larger. It even has the potential to cut the manufacturer's income because it allows the user to substitute components from other companies. For the computer owner, however, a bus design is a big advantage, primarily because of its versatility and expandability. In particular, it makes it much easier to adapt your computer to uses other than those for which you originally bought it.

One of the earliest and most popular bus designs was the S-100 bus which was first used by many of the smaller manufacturers making CP/M-80-based computers. Because it developed rather informally into a standard, there are products on the market described as S-100 compatible that will not work together. In 1982, the Institute of Electrical and Electronic Engineers (IEEE) formed a committee to define a rigorous, written standard based on the S-100 bus. The standard is known as IEEE-696. All products that meet this standard should work properly together.

There are two other busses that have become semi-official standards because of their manufacturers' clout in the market. The Apple II was the first of these. Its use of a system bus was one advantage it had over its early competitors, such as the Commodore PET and Radio Shack TRS-80 Model I. There are now hundreds of different boards available for the Apple II and there are other computers, such as the Franklin Ace and the Basis, that will accept those boards. The IBM PC system bus has reached a similar status. There may be somewhat fewer boards available for it now, but there are many more brands of computer using its bus design than there are using the Apple II design.

DATA STORAGE

In order for a microcomputer to work with numbers and letters, it must have some place to store them. In most microcomputers there are three levels of storage - internal registers, main memory, and mass storage.

Internal registers are so-called because they are built into the microprocessor chip. Each register is usually one or two bytes in length and there are typically 10 or 15 of them in a particular microprocessor. The registers are where all of the action takes place in a microcomputer; to add two numbers together the computer will load them into registers and then add the registers together. This means that while a program is running, the registers will be changing hundreds of thousands of times per second. Because the registers are used this way, and because there are so few of them, there has to be another, larger place outside the microprocessor to store information.

That's what main memory, (or central memory or just memory) is for. This is located inside the microcomputer and sometimes on the same board as the microprocessor, but not actually inside the processor as the registers are. This memory is on chips much like the microprocessor in appearance, but generally much smaller in size. The problem with this memory is that while there may be a lot of it (16K bytes up to 512K bytes or more) it's still not large enough to store every piece of data or every word of every document that you might want to process on your computer. In addition it isn't easily interchangeable. You wouldn't want to take the cover off your computer, unplug a few chips and plug in some others every time you wanted to run a different program. And finally, most memory is volatile, meaning it retains its contents only while the power is on. So we need yet another form of storage that solves these problems.

That is where mass storage, usually in the form of disks, comes in.

The most common type of disk storage on microcomputers is the floppy disk, but the hard disk, a more advanced and more expensive system, is becoming more common. Disk storage capacities start at 100K bytes and range up to 20M bytes or more. There are some other types of storage that serve the same function - permanent storage of programs and data outside the computer - but they generally have serious drawbacks. Two of these methods are paper tape storage and cassette tape storage. The availability of inexpensive floppy-disk systems has for the most part eliminated these other methods. However it should be noted that cassette tape recorders have two significant advantages for work in the field - they are light and compact and they can run on batteries. In fact Epson has made excellent use of a microcassette recorder in their HX-20 "notebook computer". So, for data collection, cassettes may still be useful; for data processing they should not even be considered. The following sections will discuss main memory, floppy disks, hard disks, and disk controllers.

MAIN MEMORY

The main memory of a computer can be thought of as a set of boxes or locations, each identified by a unique number known as its address. Each box contains one byte of information which may be part of a program (an instruction), a character, a number, or any number of other things. The microprocessor has very rapid access to main memory, but there are really only two things it can do with it - inspect the contents of a location or alter the contents of a location. These two operations are known respectively as reading and writing.

In regard to memory sizes, there is a common misconception that the size of a byte is different depending on the microprocessor being used. This is not true. A byte is always 8 bits; anyone who uses the term any other way is incorrect. A 16-bit microprocessor deals with 8-bit bytes just as an 8-bit microprocessor does; it just handles two of them at one time. A 16-bit microprocessor with 64K bytes of memory has exactly the same amount of memory as an 8-bit microprocessor with 64K bytes.

Types of Memory

Most microcomputers contain two kinds of memory - ROM (Read-Only Memory) and RAM (Random-Access Memory). The contents of ROM is predetermined by the manufacturer. It is used to store programs and information that are to be a permanent part of the computer system. This often consists of such things as a bootstrap loader, a keyboard monitor, an operating system, or even a BASIC interpreter. Since its contents cannot be changed (that's what read-only means) it cannot be used for storage of your programs or data. It is often described as nonvolatile, meaning that its contents are retained even when the power is turned off. (A moment's thought should reveal that this has to be true to enable the manufacturer to ship the machine to you with the contents of ROM intact.)

RAM is the real working storage of your computer, the place that programs are stored while they are running, where your data and words are stored while they are being processed. The computer can both read and write the contents of RAM. It is volatile, that is, whenever the power is turned off its contents are lost. Microcomputers often give you a choice of how much RAM you want and with most of them you can add more (up to a certain limit) after you buy the computer.

Memory Size

The maximum amount of memory that a computer can use is determined by the choice of microprocessor. The 8080 and 6800 families can address up to 64K bytes of memory, the 8086 family can address up to 1M byte, and the 68000 can handle 16M bytes. The general rule is that 8-bit processors can use a maximum of 64K while 16-bit processors can use much more. There is a technique called bank-switching which lets an 8-bit processor use more memory by dividing the memory into blocks (or banks) of no more than 64K and then switching between banks as needed. This tends to slow down memory access and to make the operating system more complex, but it can help to minimize disk accesses and can thereby speed up overall operation. As users' demands for memory have grown, more manufacturers have begun doing this.

The amount of RAM a computer has is a very significant indication of how powerful it is, how flexible it is, how easy it is to use, and how large a task it can handle. The reasons for this are intricately linked to software design. Remember that what you can do with your computer depends almost entirely on the software that you can run on it. It is generally true that for a computer program to be fast, powerful, and easy to use, it must be large and complicated. It is possible with a small memory to swap things in and out of memory so that only the active part is in memory at a given time, however this is complicated to program and can be extremely slow in operation. A software designer can produce a better, more reliable program if this is not necessary.

Unfortunately, if programmers designed all their programs so they required extremely large amounts of memory, only those with larger computers would buy them, and the programs wouldn't sell many copies. On the other hand, if they designed a program to run on the smallest possible machine, the program would be too limited to interest those who have machines with more memory. What the software designers do is to try to follow the trends of the hardware market.

All indications are that the hardware market is moving quickly toward larger and larger memories. Memory is becoming cheaper every year. People who have older microcomputers are adding more memory to them and people who purchase microcomputers are including large amounts of memory from the beginning. Software designers have responded by producing better, but larger, programs. It is more and more common these days to see software packages that require 64K of RAM, and for machines like the Apple III or IBM PC it is not unusual to find programs that require as much as 256K of RAM.

The amount of ROM a computer has is not as significant as the amount of RAM, although there are some cases where a manufacturer's intelligent use of ROM can be an advantage to you. A good example of this is the IBM PC, which has most of its BASIC language stored in ROM. This means that when you run a BASIC program on this computer, some of the RAM that would otherwise have to be used for the BASIC language is available to your program. An IBM PC with 64K of RAM can run a BASIC program over 41K in size, while a typical CP/M-80 computer with 64K of RAM is limited to about 30K for BASIC programs. Note that because the ROM in the IBM is used for BASIC it does not give you any advantage when running non-BASIC programs (like VisiCalc, Wordstar, etc.).

Adding Memory

It is quite common for users of 16-bit computers to buy them with 64K to 256K of memory. When the machines are put to use, the need for more memory often arises. There are two ways that more memory can be added.

Some 16-bit computers can be bought with a minimal amount of memory, typically 64K, which can be increased by installing additional chips on the system board. The system board contains empty "sockets" into which the memory chips can be installed. The amount of memory that can be added is limited by the number of sockets that the manufacturer provides. The IBM PC, for example, allows up to 256K bytes on the system board. Memory expansion beyond the manufacturer's system-board capacity must be done using the second method, described later.

Installation of RAM chips in sockets is not a difficult task but it does require care, because it is possible to damage the chips or the computer itself. If you do not have any electronics experience or some detailed instructions written specifically for your brand of computer, you should not attempt to do it yourself. The chips do not have to be purchased from the manufacturer of your computer, as there are many companies selling equivalent chips. If you tell the chip supplier what computer it is for, he can probably tell you what chip you need. If not, you may have to get information from the computer manufacturer as to what type of chip is needed and what its "access time" must be.

There are two types of RAM chips - dynamic and static. Most microcomputers use dynamic RAM because it is cheaper. Static RAM has several advantages, including the need for less support circuitry, the ability to retain data with minimal power consumption, and a shorter access time. The two types are not interchangeable so you must get the right one for your computer.

The access time is the length of time it takes for the chip to "deliver" data to the CPU. This is expressed in nanoseconds (nsec) which are billionths of a second. The access time for dynamic RAM is typically in the range of 100 to 200 nsec. If the access time is too long, it may cause errors because the data will not be there when the

CPU requires it. It does not hurt to use chips with a shorter access time than your computer requires but they cost more and will not improve its performance any.

The alternative method of adding memory applies to computers that include slots for expansion boards. This requires buying a complete printed circuit board which plugs into a slot in the computer. If you intend to do this, you should make sure there will be enough slots to hold the memory you want after all of the other accessory boards have been installed. Usually only one or two slots will be needed, since some boards are available with as much as 512K of RAM. These boards can usually be purchased with a minimum of 64K and have sockets allowing for additional memory. These sockets may be filled with chips when you purchase the board or you can add chips later in the same way you would add them to the system board.

There are a number of companies that sell memory upgrade kits for 8-bit computers, particularly the Apple II and Radio Shack Model II, that expand their memory beyond 64K bytes. These are usually sold in conjunction with a particular software package, such as VisiCalc, and what they promise is an extended workspace with that package. Do not assume that these are general-purpose memory expansions! In almost all cases, the extra memory can only be used by the particular package that they are selling, and you will not be able to take advantage of it with any of your other programs. On the other hand, there are some recent 8-bit computers, such as the Apple IIe, Apple III, Radio Shack Model 4, and Osborne Executive which offer more than 64K of memory as a manufacturer-supported, standard feature. For those machines you can count on the availability of software to take advantage of the expanded memory.

Recommendations

It is strongly recommended that you buy a computer with a minimum of 64K of RAM. If you get a 16-bit computer, such as an IBM PC, you should get a minimum of 128K of RAM. Note that it is possible in most cases to add memory later, if you decide that you need it. However, if you are not technically inclined you may not be comfortable opening up your computer to do it yourself and you may not be conveniently close to a dealer who can do it for you. In addition, it may be easier to get administrative approval for it if it is part of the original purchase than if you make a separate request later.

You should be aware that some older programs designed for smaller memory sizes cannot take advantage of the increased capacities of today's microcomputers. A particular word-processing program, for example, might have exactly the same performance on a computer with 64K of memory as it does on one with 128K of memory. In this case, the additional memory would not do you any good. This is changing rapidly, with the newer programs either requiring large amounts of memory or at least benefitting from it. Buying a computer that can use 128K or more memory is one way to avoid having your purchase become technologically obsolete too quickly.

FLOPPY DISKS

Floppy disks are so-named because they are small circles of very flexible Mylar plastic .003" thick. The disk is permanently encased in a square vinyl envelope or jacket with several openings of different sizes cut in both sides to expose the surface of the disk. The jacket gives the disk more rigidity than it would have on its own, but it is still flexible enough that it must be handled with care, because bending or folding it will cause permanent damage. The jacketed disk comes in a cardboard sleeve which protects the disk surface somewhat by covering the openings in the jacket.

A floppy disk is often described as a cross between a cassette tape and a phonograph record. The disk itself is coated with a magnetic material much like that used on recording tape. It can be written on or read from using methods similar to the recording and playback functions of a tape recorder. You can buy disks containing "prerecorded" programs or you can buy blank disks to store your own programs and data. The disk has a one inch hole in its center much like that in a 45 rpm phonograph record.

The piece of hardware that reads and writes the disk is called a disk drive (often shortened to just "drive"). The drive has a door on the front of it which when opened reveals a slot the size of the disk. To use a disk you remove it from its sleeve, slide it into the slot, and close the door. The drive clamps onto the disk by its center hole and when the computer needs to read or write the disk it starts spinning it at 300 revolutions per minute (rpm) or more. The reading and writing is done by a head (much like that in a cassette recorder) which moves to the appropriate position on the disk and moves down to contact the spinning disk. There is a long, narrow radial opening in the jacket of the disk to allow the head to contact the disk at any point from its outer edge to near its center, in much the way you can move the needle to any point on a phonograph record. Unlike a record, the disk is smooth, with no grooves to guide the head. The head must have its own controller to move it quickly and precisely to the right point on the disk.

These mechanical characteristics of the floppy disk and drive make the disk very susceptible to wear. The disk spins while its jacket is held in place, so there is a problem of friction between them. Even though there is a coating on the inside of the jacket to reduce friction, it cannot be eliminated. The other source of wear is the head pressing against the disk as it rotates. These problems are minimized by the fact that the disk drive leaves the disk stationary with the head raised from it until the moment when the computer needs to read or write on it. Nevertheless, disks will wear out and generally should not be expected to have a life span of more than a year or two of regular use. This can be shortened considerably if the disk becomes contaminated by dirt, smoke, or fingerprints.

Sizes

There are two common sizes of floppy disks. The original, larger size, introduced by IBM in 1971, is 8 inches in diameter. The smaller size, introduced several years later, is 5 1/4 inches in diameter. Several manufacturers have developed even smaller disks, between 3 and 4 inches in diameter. There are only a handful of computers using these and they are too new and unstandardized to be considered in this paper. The most prominent one in the market right now is a 3 1/2 inch disk designed by Sony that is used in Sony and Hewlett Packard computers. The 8 inch disks are often referred to as diskettes, the 5 1/4 inch ones as minidiskettes, and the smaller ones as microdiskettes. A disk drive designed for one size of disk cannot use disks of another size. Until recently, 8 inch disks were the most popular size. In the last two years 5 1/4 inch disk drive sales have surpassed those of the larger ones and their sales are expected to continue to grow rapidly while sales of 8 inch drives remain steady or fall.

Compatibility

Although the two larger disk sizes have been standardized, there is no standard way of writing data on them. The fact that two computers use the same size disk does not mean that one of them can read a disk written by the other. The disk will fit in the disk drive and the drive will spin it around but the computer will not be able to find the data or programs on it unless it was written in a precisely defined way. This lack of compatibility between disk formats is a major problem in microcomputers and it may be a major factor in your choice of a brand of microcomputer. If you need to exchange programs or data with someone else, in many cases the only practical way to do this is via floppy disk. Unfortunately, it is not enough to know that your computers are from the same manufacturer or that they use the same operating system. Some examples:

1. A Radio Shack Model II and Radio Shack Model III cannot exchange disks.

2. An Osborne running CP/M-80 and an Apple II running CP/M-80 cannot exchange disks.

3. An IBM PC running CP/M-86 and an IBM PC running PCDOS cannot exchange disks.

4. An Apple II running Apple DOS cannot read disks from an Apple II running CP/M-80 or an Apple II running the Apple Pascal system.

A partial solution to this problem is available in the form of disk file conversion programs that allow a particular computer to read or write disks in something other than its standard format. The conversions listed as items 3 and 4 above can be handled by programs of this type. Such programs typically cost $40 to $200.

Recording Format

The recording formats used differ in three main ways - the number of tracks per inch (tpi), the number of bits per inch (bpi), and the sector size. To understand these you need to know a little more about how the information on a floppy disk is organized.

Unlike a phonograph record, where the music is recorded as a continuous spiral from the outside of the record to the inside, the information on a floppy disk is written as a set of concentric circles, called tracks. Within each track the information is recorded in sectors, each sector being an arc of the circular track. All tracks on a given disk have the same number of sectors and each sector contains the same number of bytes of information. In order to access a particular piece of information the disk drive head is moved into position over the desired track, the head is lowered so that it touches the disk, and when the desired sector goes by it is read or written. The total amount of information on a disk can be increased by putting more tracks per inch, more bits per inch, or using larger sectors.

The number of tracks per inch measures how closely those concentric circles are spaced, or, more precisely, how many tracks are recorded per inch of the disk's radius. To increase this requires that the disk clamping and spinning mechanism, as well as the head positioning mechanism, be made more precise. The most common track densities are 48 tpi and 96 tpi which allow a total of 40 or 80 tracks on a 5 1/4" disk.

The number of bits per inch measures how many bits of information can be recorded on one inch of arc within a track. This depends on the recording method, the design of the head, and the magnetic qualities of the disk itself. The recording density is typically in the range of 500 to 1000 bpi.

The sector size tells how many bytes there are in each sector.

There is a certain fixed amount of overhead or wasted space required between sectors on the disk. This means that the smaller the sectors are, the more sectors there will be per track and thus the more wasted space there will be. So larger sectors mean that more information can be put on a disk. The disadvantages of larger sectors are that larger areas of memory must be devoted to buffer space for reading them in, that it may take longer to read in small pieces of data (because the drive always reads one entire sector at a time, never a partial one), and that small files may waste space on the disk (because they must occupy at least one entire sector, no matter how small the file is). There are usually 8 to 26 sectors per track and the sectors contain 128 to 512 bytes each.

Density

You will rarely find the above information when reading about the disk capacity of a particular computer. The capacity will usually be given in kilobytes, such as 140K or 360K bytes. You will however often encounter the terms single density and double density. These are very imprecise terms which differ greatly in meaning from one manufacturer to another. The density usually refers to the number of bits per inch, so if a particular manufacturer offers both single-density and double-density systems the double-density one will have twice the bpi of the single-density one. This will of course double the amount of information on the disk.

The problem is two disk systems of the same size from different manufacturers may both be described as double-density and yet be very different in any of the three parameters described above. You will find double-density 5 1/4" disk drives with capacities from 120K up to 200K bytes. The point here is that the density description tells you very little about the actual capacity of the disk and it tells you nothing about the compatibility of that disk with other systems.

What it does tell you is what kind of blank disks you need to buy to use with the system. Double-density systems, because they are recording more information in the same space, require higher quality disks, with smaller magnetic particles and a smoother coating. The best disk manufacturers test every disk that they sell, rejecting those that show any errors. Because double-density recording is more demanding, it results in higher reject rates. For these reasons double-density disks cost more than single-density ones. It is possible to use a blank disk designated as single-density in a double-density drive but it is not recommended. Doing so will usually result in more disk errors earlier in the life of the disk than you would get using the proper disks.

To get even more storage space on a disk, some manufacturers now use quad-density drives. This usually means the drive will write 96 tracks per inch (versus 48 tpi for double-density). Double-density disks will often work in these drives, but the more costly quad-density disks may give better results.

Double-Sided Disks

There is one other way that the capacity of a disk can be increased - by recording on both sides of it. All of the discussion above assumed what is called single-sided recording. There is one head per disk drive and it can only read and write on the side of the disk that is facing it. A double-sided disk drive has two heads, one of which contacts each side of the disk thereby allowing twice as much information to be recorded. Double-sided double-density 5 1/4" disk drives have capacities ranging from about 300K to 400K bytes.

As with double-density, there are double-sided disks sold specifically for use in double-sided drives. As you would expect, they cost more than single-sided ones. The 8 inch double-sided disks are physically different than single-sided disks in that they have an index hole located in a different place. For this reason those disks are not interchangeable; you must buy the correct kind for your machine. In the 5 1/4 inch size, the single-sided and double-sided versions are constructed exactly the same way. The single-sided ones even have a magnetic coating on both sides. The difference is in the manufacturer's testing. Double-sided disks will have been tested on both sides while single-sided disks will only have been tested on one side. The result is that blank 5 1/4 inch disks sold as single-sided can usually, but not always, be used as if they were double-sided.

Recommendations

Disk capacity, like memory, is an indicator of the capability and ease of use of a computer. It is recommended that you not even consider a system where a single disk will hold less than 200K bytes, and a capacity of 300K or more would be preferable. You may think you can compensate for a low individual disk capacity by adding more drives, but this may not work if you have a single set of data that is too big for one disk.

200K is equivalent to 2500 lines of 80 characters or about 100 typed pages. There are times when it is convenient or even necessary to have two slightly different copies of one file on the same disk, limiting you to files of half this size. For example, some word processors keep the latest revision of a document and the previous revision under different names and some data managers, when sorting files, must have the original and the sorted data on the same disk. If you are working with smaller files, a 200K disk will allow you to include the operating system and some programs along with your data, which can be a tremendous convenience. It will also allow you to set up program disks that include several programs, such as a spreadsheet, a word processor, and a communications program, reducing the amount of disk swapping that you have to do.

If you are familiar with the characteristics of some of the microcomputers on the market today, it may have occurred to you that setting a minimum disk size of 200K would disqualify the Apple II, possibly the most popular microcomputer in the world. Yet many people have used Apple II's in development projects for several years and have been quite successful with them. The reason for this is that those people generally had fairly limited expectations of a computer system or a great deal of patience and perseverance in trying to make the computer do what they wanted to do. They probably also got a lot of experience at swapping disks in and out of their drives. Today there are many popular machines that have larger disk capacities, greatly easing this burden on the user. The Apple has fallen behind in this respect.

The other side of this argument is that floppy disk capacity is not everything. If you have some important reason for choosing a particular computer, such as the ability to run a particular software package or the need to exchange disks with someone else who has that kind of computer, that may be more important than disk capacity. If the machine that you choose has low-capacity floppy disks you may be able to compensate by adding a hard disk (see the following section).

A second strong recommendation is that you get at least two disk drives. Working with a single disk drive is very tedious and time-consuming because you have to switch disks so often. If you are relying on the system heavily you should also have one spare floppy-disk drive to be used if one of your others malfunctions.

Finally, if it is important to you to be able to exchange data or programs with someone else, you should make sure that your disk systems are compatible. In order to ensure this compatibility you need to know the make and model of the other computer, what operating system it uses, and the size (5 1/4" or 8") and capacity (in Kbytes) of the disk drives on it. If you have this information, a dealer should be able to tell you if the computer you are considering will be able to exchange disks with the other one.

HARD DISKS

The hard-disk drive is a higher priced, higher performance mass storage device. The kind of hard-disk drive used on microcomputers is known as a Winchester drive. The Wincherester design was developed for mainframes in 1973 and since then smaller versions have been introduced for microcomputers.

Characteristics

The hard disk gets its name from the fact that the disk is made of polished aluminum, in contrast to the flexible plastic floppy disk. The disk is machined to extremely close tolerances of roundness and flatness. It is coated with metal oxide much like that used on a floppy disk.

In almost all of its operating characteristics it is very different from a floppy-disk drive. The read/write head does not touch the disk, but rather floats just microns above it on a cushion of air. The disk itself rotates at a much higher speed - 3000 rpm or higher - and it does so as long as the computer is turned on. It draws quite a bit of power, generates a lot of heat, and may be trouble-prone in a hot environment. Because of the incredibly close tolerances, the system is extremely sensitive to dust, dirt, etc. Most will not operate at high altittudes (above 15,000 feet). The drives are usually built as sealed systems, with no way to remove the disk. This means that you cannot take one disk out and put another one in; you are limited to the amount of information that can be stored on a single disk. It also means that you cannot move hard disks from one computer to another, as you can with a floppy disk, unless you take the entire disk drive.

Most of them are rather delicate and cannot take hard knocks as well as a floppy-disk drive can. A "head crash", where because of some electrical or mechanical problem the head comes in contact with the surface of the disk, will usually destroy the disk and cause the loss of a lot of data. This kind of failure will usually require specialized service, meaning weeks or months delay time. And because hard disks cost so much ($1,000 to $15,000) it is usually impractical to have another unit as a backup as is often done with floppy-disk drives.

Capacity and Speed

With all these problems you may wonder why such a big deal is being made about hard disks. There are two answers - capacity and speed.

The smallest hard disks have a capacity of 5M bytes, equivalent to 15 double-sided, double-density 5 1/4" floppy disks. They are commonly available in sizes up to 40M bytes. (Hard disks are often advertised with both "formatted" and "unformatted" capacities. The formatted capacity is the fiqure that is important to you.) For any project dealing with large quantities of data this is a tremendous advantage. Many programs will not work with data that occupies more than one disk, so with floppy disks you are limited to data sets of a few hundred kilobytes. Even if a program does allow data to "span" several disks, it can be time-consuming and tedious to be continually swapping disks. A hard disk can eliminate all these problems.

Hard-disk drives can also read and write data much faster than a floppy-disk system can. For one thing, a hard disk is always spinning, while a floppy disk doesn't start spinning until it needs to read or write, causing a slight delay while the disk gets up to speed. The higher rotational speed means the head does not have to wait as long for the desired sector to pass beneath it. And finally, the average access time, the time it takes the head to move to a track and get prepared to read it, is usually shorter. A program that does a lot of input and output can be very slow on a floppy-disk system. Switching to a hard-disk drive can speed this up tremendously.

Backup

Unfortunately the higher capacity works as a disadvantage when it comes to making backup copies of your files. Consider that it may take 15 to 100 floppy disks to hold the contents of one hard disk and that to be reasonably safe you should always keep at least two backup copies of each file. This means that you can't backup the entire system every day because it would take too long. If you could keep track of what files have been modified each day you could copy just those files at the end of the day but most operating systems cannot keep track of this for you. An even worse problem is that most operating systems have no way of splitting up a file that is larger than one floppy disk, so these may require custom software to divide them into manageable sizes for backup purposes.

There are some operating systems, which are designed to handle these problems. One example of this is IBM PCDOS 2.0 and the equivalent Microsoft MSDOS 2.0. It has a BACKUP command specifically for hard-disk users. The operating system keeps a record of which files have been altered since the last BACKUP, and can automatically make copies of only those files. It will also automatically divide any file that is too large to fit on a single floppy disk.

It is, of course, possible to have two hard disks with one acting strictly as a backup. With this kind of system you might make floppy disk backups once a week to protect against some catastrophe that could destroy both hard disks. Another method of backup is a high-speed tape drive, often called a "streaming" tape drive. This gives a reasonably quick way of backing up an entire disk, but the tape is not usable by itself. If you lose data from the disk, the tape can be used to restore it, but if the disk has to be sent away for repairs, the tape drive cannot be used in its place.

Removable Hard Disks

There is another kind of hard-disk drive that is just appearing on the market. It is known by several names, including removable hard disk, exchangeable hard disk, or cartridge hard disk. In this design the disk itself is enclosed in a small plastic box which fits into a slot in the disk drive in much the same way that a floppy disk does. The disk drive prices are comparable to those for regular hard disks (which because they are not removable are sometimes referred to as fixed-disk drives) and the cartridges cost approximately $100.

These offer several advantages over fixed disks, the most notable being that by buying several cartridges you can store tremendous amounts of data, even if each cartridge is as small as 5M bytes, without buying another drive. A cartridge gives you the same kind of flexibility in this respect as a floppy-disk drive does. In addition, if a disk is damaged but the drive is still operating, you don't have to send the entire unit back for repairs as you do with a fixed hard disk.

Removable disks still present the problem of backup methods. You can copy from one cartridge to another using a single drive but you might have to swap cartridges 100 times or more to copy the entire disk. (A single-drive copy works as follows: the computer copies a portion of the disk into memory, asks the user to switch disks, copies from memory to the new disk, and then asks the user to switch back to the orginal disk. This is repeated until the entire disk has been copied.) Two cartridge drives would solve this problem but would be quite expensive.

Probably the best solution to all these problems is a combination drive which includes both a fixed hard disk and a removable hard disk in the same cabinet. This gives you a relatively easy backup method, unlimited capacity (as long as no single file is larger than the size of one disk), and costs less than buying two separate drives. It still has the disadvantage that the whole unit must be returned for service, leaving you without any disk drive under those circumstances.

Recommendations

It is difficult to make a firm recommendation regarding hard disks. For applications involving large data files, their advantages can be enormous. They are still a fairly new product, meaning their reliability in a hostile environment is unknown. If you have a use for one, the money to pay for it, and can locate it somewhere that dust, heat, and high or low humidity are not a problem, you will probably be very pleased with its performance.

DISK-DRIVE CONTROLLERS

All communications between the computer and the disk drive are usually handled by a separate interface board called a disk controller. This is usually mounted inside the case of the computer and connected through a cable to the disk drive which may be in a separate enclosure. There are a few computer designs which put the controller board inside the disk drive rather than inside the computer, but this is uncommon.

The controller has responsibility for positioning the head properly, raising and lowering it, reading or writing data when the right sector comes around, and transmitting the data to or from the drive. A single controller can usually handle from two to four disk drives. If you are thinking of expanding your system by adding more disk drives later, you should find out whether your first controller will be able to handle them or if you will have to buy an additional controller as well. If your system is going to include both floppy disks and a hard disk you will usually need a controller board for each type.

If you buy a fairly standard floppy-disk-based computer system, the controller shouldn't be of much concern to you. It will be included in the system either as a standard component or as a separate (but not really optional) item. If you are trying to add disk drives of a different type or size to your system, you should make sure that you have an appropriate controller. There are a number of hard disk drives advertised at very low prices ($800-$1500). Many of these have such low prices because they come without controllers, without cabinets, and without proper software to allow your computer to use them. Before adding any disk systems from a different manufacturer, you should make sure that you are getting a complete system that will plug into your computer and work properly without any adverse effect on your current operating system or software.

KEYBOARDS

The keyboard is the only part of the computer with which you will have a lot of physical contact. For that reason it is often the major factor in how comfortable the computer is to use for long periods of time. Its design will also affect how quickly an operator can accomplish a task on the computer.

Physical Characteristics

The most flexible arrangement is to have a keyboard that is physically separate from all other parts of the computer. This allows the user to place the keyboard in a comfortable location in relation to the other components. Everyone's working posture is a little different and the detached keyboard allows each person to easily alter the arrangement to suit themselves. The most important spatial relationship is that between the keyboard and the display. A machine that combines the keyboard with other components, such as the CPU or disk drives, but has a physically separate display, can be almost as flexible in this respect as one with a totally separate keyboard. Machines with separate keyboards will vary in their adjustability according to the length and design of their connecting cables and how they are attached.

Another desirable adjustment is the angle of the keyboard. Most recent machines with separate keyboards have adjustable feet that can raise or lower the back end of the keyboard. A continuous adjustment here is better than a two-position one.

Keyboards differ greatly in their "feel". This depends partly on the amount of travel of the keys - how far they must move before the keystrokes register. It also depends on the amount of resistance the keys offer. Some keyboards are very stiff and others are very soft. There is a qualitative aspect to the resistance of the keys as well. Two keyboards that take the same amount of pressure can still feel very different. The feel of a keyboard is very subjective and can only be evaluated by the person who will be using it.

Many keyboards have a feature called autorepeat or typematic. This means that if you press a key and hold it down, the corresponding character will be repeated until you release the key. Keyboards without this feature have a separate REPEAT key which must be used in combination with the key that you wish to repeat. This is a less convenient arrangement.

Typing comfort and speed may be affected by the shape of the keyboard. One variable here is the shape of the tops of the keys, i.e. whether they are flat or have a shaped indentation in them. Indented keys are often referred to as "sculptured". Sculptured keys are usually easier to type on. The way the rows of keys are positioned with respect to each other is also significant. In this respect a keyboard may be flat or "dished". A flat keyboard when viewed from the side will have all of its keys in the same plane. A dished (or contoured) keyboard will look curved when viewed from the side. If you imagine a plane going from the top row of keys to the bottom row of keys, the middle rows of keys will be below that plane. If you have trouble imagining this, look at an IBM Selectric typewriter or an IBM keypunch machine; they have dished keyboards. This is a desirable feature which is usually found only on more expensive computers.

Key Groupings

The main part of a computer keyboard looks very much like a typewriter keyboard. It usually will have three or four more keys with computer-related functions like CONTROL, ESCAPE, or BREAK and it will have a few more special characters like <, >, ^, {, and }. The major difference from a typewriter is that it may have up to three other sections of keys.

The cursor-control keys (often shortened to cursor keys) are four keys with arrows on them that are usually grouped together, often in a diamond pattern. The cursor is a visual marker (often a blinking rectangle) that shows the current position on the display. The cursor-control keys are used to move the cursor to a different position, with the four arrows corresponding to the four possible directions of movement on the screen.

A numeric keypad (or number pad) is a section that is particularly important if you need to enter a lot of numeric data from the keyboard. It has the numbers positioned in a calculator-style block and usually includes a decimal point, a minus sign, and an ENTER key as well. Sometimes the cursor keys will be combined with the numeric keypad, with another key choosing which function they will perform. Programs like VisiCalc which can benefit from a numeric keypad and cursor keys make this combined arrangement cumbersome.

The other section that is often found is a set of definable special function keys or "soft keys". There are usually four to twelve of these. They can have different functions for different applications and if you do your own programming your program can define their functions. They are particularly useful for things such as word processing because they can allow you to do something with a single keystroke that might otherwise have required typing in a command of some sort. These are usually easiest to use if they are placed in a single row just above the top row of typewriter keys, but spaced apart from them. With any other arrangement it is harder to hit the desired key quickly and without error. Many application programs are written to take advantage of a particular machine's special function keys and they will often include labels to go on or next to the keys to show their function for that program. Function keys are a definite plus in making a computer easier to use.

Key Placement

The arrangement of keys within the typewriter portion of the keyboard varies somewhat from one computer to another, but the differences are usually limited to the locations of little-used characters. However when IBM introduced their Personal Computer this changed radically. They made two major changes to their keyboard, moving the left-hand shift key and the RETURN (or ENTER) key farther to the left and the right, respectively, than any other keyboard. They have been criticized very heavily for this, yet their computer has sold so well that other companies are now copying its layout. Anyone who works exclusively on this keyboard can adapt to these new locations but it can be a major problem for those who must use other keyboards as well. It has been seen as such a problem by some people that several other companies are offering replacement keyboards for the IBM with the keys in their standard locations.

Some computers have a single key to reset the computer or stop execution of a program. This is a poor design because it is very easy to hit a key accidentally, possibly causing the loss of data or programs. The Radio Shack Model II is particularly bad in this respect because its BREAK key is close to the RETURN key. Any RESET or BREAK function should either be done by a separate button not on the keyboard or it should require the simultaneous use of two or more keys.

Other Languages

Some computer companies make special versions of their computers designed for languages other than English. These versions have different keyboards to include whatever special letters or symbols are required for the desired language. Apple and IBM are two companies that have models like this. In some cases the special models may be manufactured outside the U.S., making them difficult to obtain here. It might require a special order through a knowledgable and perseverant dealer or even a direct factory order. Overseas it might be easier to obtain the foreign language version than the standard English version.

Recommendations

The importance of the keyboard in your choice of a computer will depend on the expected uses of the computer. If it will be used largely for word processing, the keyboard should be one of the most important factors. It should be a separate unit and have as much adjustability as possible. Special function keys can be a big advantage here, if you find word processing software that takes advantage of them. If you expect a secretary to use the computer as a word processor for some work and to use a typewriter for other work, it is extremely important that the computer keyboard have a standard layout. Forcing someone to switch back and forth between a standard keyboard and the new IBM keyboard described above can cause many errors and erase some of the productivity gains of using a word processor.

The other major consideration in a keyboard is that for extensive numeric data entry it is almost mandatory that you have a numeric keypad. For some computers that do not have this as a standard feature it is possible to buy one as an accessory.

DISPLAYS

The video display screen is the primary output device for microcomputers. Anyone using the computer will spend a lot of time looking at the display, so its quality and characteristics are very important.

The video display consists of two parts, the video display board (or interface) and the video display screen. The video display board is inside the computer and contains the circuitry to generate signals to send to the screen. The screen, of course, is the television-like device on which you read the computer output. The screen is often referred to as a monitor, a CRT (cathode-ray tube), or a VDU (video display unit).

The video interface board is not usually an option, although the IBM PC, for example, offers a choice of two different boards. The screen is often built-in, but if it is not you may have quite a bit of flexibility in choosing one from another manufacturer.

Video Display Board

Many of the characteristics of a computer display are determined strictly by the display board; hooking up a different screen to the computer will not change their characteristics at all.

Characters on a video screen are made up of small dots arranged in the desired pattern. The dots are often referred to as pixels, an arbreviation for "picture elements." One important characteristic of the video board is the number of dots used to form the characters. The most common design is to use a block five dots wide and seven dots high, described as a 5 X 7 matrix, within which to form each character. This produces characters in which the individual dots are quite noticeable and which can be hard on your eyes if you work with it for several hours. More sophisticated video boards will use a 7 X 9 or 9 X 14 matrix, giving a noticeably easier-to-read display.

The video board also determines how many characters can be displayed on the screen. The most common computer display size is 24 lines of 80 characters, although there are a few computers which will display as many as 132 characters per line. Many microcomputers of the last five years have had displays with as few as 40 characters per line or as few as 16 lines, neither of which is really suitable for research or administrative use. Manufacturers have recognized this and in 1983, three very popular microcomputers which were deficient in this respect, the Apple II, Radio Shack Model III, and Osborne 1, have been replaced by new models which have full 24 line by 80 character displays. There is now almost no reason to settle for a smaller display.

Another characteristic of the video board is whether or not it can display graphics. There are two kinds of graphics which we must differentiate here. The simpler type is called block graphics or character graphics. For this purpose most computers define 32 special graphics characters each of which occupies one character position on the screen. They consist of lines, squares, rectangles and corners of different shapes and sizes. These can be displayed in any or all of the 24 X 80 screen positions in the same way that any other characters can. By positioning the right characters next to each other you can create simple pictures or diagrams, such as bar graphs. Almost all computers can produce this type of graphics.

Screen graphics (also known as true graphics or dot-addressable graphics) lets you control whether each individual dot on the screen is on or off. You can draw pictures with much more detail this way. The amount of detail is determined by the total number of dots that the board will display on the screen. This is usually referred to as the resolution of the video board. Some computers offer more than one level of resolution, usually referred to as low, medium, and/or high resolution. For example, the IBM PC has medium-resolution graphics which can display 320 dots horizontally and 200 dots vertically, and it also has high-resolution graphics which displays 640 X 200 dots. The Apple II has low-resolution graphics which is essentially block graphics with 40 blocks across and 48 blocks vertically. It also has high-resolution graphics which displays 280 X 192 dots. You can see that the terminology differs from one manufacturer to another, as the Apple high-resolution mode has slightly less resolution than the IBM medium-resolution mode.

The video board also determines whether the computer can generate a color display. This can be a very useful capability if you want to do fancy graphics work, but for straight numeric or text displays it is not particularly helpful. To take advantage of a color video board you must buy a color monitor, which costs three to four times as much as a standard monitor. Even then you cannot get a paper copy of the display unless you have a color printer or color plotter.

A video board must have some memory (RAM) available to it to store information about what is currently being displayed. The amount of memory varies, but it may be as much as 8K-16K bytes when graphics are being displayed. Some boards use part of the computer's central memory for this, reducing the amount that is available for use by programs. Other boards have their own RAM in addition to the computer's. A computer with this design having 64K of memory would have more usable memory than another 64K machine whose video board preempted the use of part of that 64K.

Some video boards can support more than one "page" or "screen" of display at a time. Only one of these is active, meaning it is being shown on the physical screen, while the others are inactive, existing only in memory. A program can write to an inactive page without disturbing the active page. A single command can change which page is active, bringing it up instantaneously on the screen. This is useful for programs that produce more output than will fit on the screen at once. For example, a regression analysis might produce a table of coefficients and goodness-of-fit statistics on one page, a plot of actual versus fitted values on another page, and residuals analysis on a third. The user could use a single key to switch between the three pages without requiring the program to rewrite them each time.

Television Sets

A computer display screen looks in many ways like a standard television set without tuning knobs. Many home or game computers are designed specifically to attach to a television so that you don't have to pay for a separate display. This should not lead you to think that a television is a substitute for a display that was designed for computer use. The cost ($150 to $300) of a computer monitor is well worth it for several reasons.

The computers that are designed for use with a television display 22 to 40 characters per line, significantly less than the 80 characters considered standard for a business computer. They are so limited because a television cannot display enough detail for 80 characters to be legible. It costs more to design a television to show that much detail. For television broadcasts the advantages are not very noticeable so the manufacturers don't do it.

Another factor in the blurriness of a television display is that extra signal processing must be done. A computer normally generates what is called a "composite video output". Before a television set can accept this, the signal must be modified to look like the kind that a television station would broadcast, known as a radio frequency (RF) signal. There is a device called an RF modulator that performs this conversion. Any computer designed to work only with a television will have an RF modulator built into it; for other computers you can buy external RF modulators. The tuner in the television is set to a specific channel, usually 2 or 3, and its RF demodulator changes the signal back to a composite video signal. This modulation/demodulation process degrades the image.

Display Screen Characteristics

The size of a display screen is measured diagonally across its face just as a television's is. Those used on microcomputers usually range from 9 inches (23 cm.) to 15 inches (38 cm.) with 12 inches (30 cm.) being most common. Some portable computers have screens as small as 5 inches (13 cm.). A 9 inch screen is the smallest size recommended for extended periods of use, but even that can be too small for two people to work at. (If you haven't used a computer much, you may be surprised at how often two or three people will gather at the computer, discussing how best to do something or looking at the screen output from a program.) A screen larger than 15 inches is suitable only for showing something to groups of people, because unless it is placed far enough away it requires your eyes to scan too far to read the text.

As with keyboards, it is advantageous for the screen to be readily moveable. A screen that is separate from all of the other components can most easily be moved to a comfortable location. Some of the most advanced screens have tilt and swivel adjustments built into them. You can also buy accessory stands that provide these adjustments for screens that are lacking them.

To minimize reflections from lights and windows, many displays have anti-glare screens. This is a very desirable feature which can make the screen much easier to read. This is achieved either by using special "etched" glass or by applying a dull coating to the glass. There are also accessory anti-glare filters that can be fitted on the front of reflective screens. You should be wary of these because adding any extra layer in front of the screen tends to cause problems with dust, dirt, fingerprints, and scratches, degrading the display rather than improving it.

A screen should have adjustments for brightness and contrast. These controls, as well as the power switch, should be located on the front panel for ease of use. These two adjustments are extremely important for getting the best possible display. Different people will have different preferences and the preferred settings will also vary with the ambient light. If you are trying to evaluate the quality of a display, in a store or elsewhere, be sure to use these controls to see if you can improve the display. The brightness and contrast interact with each other, so it takes some trial and error to find the best settings. Incorrect settings can make an excellent screen look very bad.

A few years ago there was some controversy about potentially unsafe levels of radiation emission from CRT's. This question arose partially because of some workers' health-related complaints after they started working with computer screens and partially because of some excess radiation problems that existed with early color television sets. Several studies have shown conclusively that today's computer displays pose no radiation hazard even to someone who works at one full-time. There are some real health problems, generally falling into the categories of vision-related (poor display quality, improper adjustments, glare), posture-related (wrong chair or keyboard height, wrong keyboard to screen positioning), and stress-related (anxiety about working with computers, unfriendly software). All of these things should be considered very carefully if you will be requiring anyone to work at the computer for long periods of time, but radiation should be of no concern.

Monochrome Displays

A display screen that can show only a single color is often referred to as a monochrome display. The background of such a screen is usually black and the characters are shown in the single color. In older screens the single color was always white, giving a display that looked much like a black-and-white television.

Some research on vision has show that some display colors other than white are easier on the eyes. Green and amber have been found to be particularly good. Most American and Japanese displays use black-and-green displays, while in Europe black-and-amber is more common. There are some colored filters available that can be placed over a back-and-white display to make it appear green or amber. These are not recommended because, although they appear to be the right color, they do not duplicate the spectrum of colors produced by a screen that actually uses a green or amber phosphor (the light-emitting substance inside the tube). This spectrum is a very important reason for the better readability of these screens.

Some displays have an inverse-video switch which will change the usual green characters on a black background to black characters on a green background. Many people find this pleasing because it is similar to a printed page with black letters on white paper and it also makes the individual dots in the characters less noticeable. It is very advantageous to have this choice on a monitor.

Monochrome displays usually require what is called a composite video signal, or video output. (One exception is the IBM monochrome monitor, which requires a direct-drive video signal, enabling it to give a higher quality display.) A composite video signal coming from a color-capable computer may contain color information, but it will be displayed in the single color of the monochrome monitor, just as a color television signal appears on a black-and-white television. However, many color combinations, say a red background with blue characters, may be so close in hue that they will produce indistinguishable shades of green on a green monitor. This means that a program designed to produce a color display may not be usable on a monochrome monitor unless you can modify the program to send a non-color signal.

If your computer has a built-in display, the documentation probably won't give you any performance specifications. If you shop for a monitor from another manufacturer, you will encounter bandwidth (or frequency response) and resolution specifications. Bandwidth is measured in megaHertz (MHz) and the higher it is the better. Monochrome monitors will usually have a bandwidth between 15 and 25 MHz. Resolution is measured in numbers of lines, either horizontally or vertically. If a single figure is given it will refer to horizontal resolution, which is always greater. Monochrome monitors will vary from about 600 to 1000 lines of horizontal resolution, and again the higher values are better.

Both of these specifications measure how sharp or detailed the screen is. You can evaluate this yourself if you have access to the monitors you are considering. Try to see all of the different display modes of the computer, including complicated graphics, with angled lines and curves, as well as text. Make sure the contrast and brightness are optimally adjusted. All displays are sharpest at the center and least sharp at the edges and corners, so be sure you look at all parts of the screen.

Color Monitors

There is a much wider variation in quality among color monitors than there is among monochrome monitors. Prices typically range from $300 to $1000. If you see a computer with a color display that has poor colors or a fuzzy picture, it is quite likely that the monitor is more at fault than is the computer.

Color monitors generally have one of two kinds of inputs, either composite video or RGB (also known as direct drive). The composite video input is exactly like what most monochrome monitors use, but if there is any color information in the signal the color monitor will display it. An RGB input has the individual colors (red, green, and blue, hence RGB) separated into individual signals, a setup which results in much truer colors. There are two different types of RGB systems, analog and digital, and you must make sure that your computer and monitor are compatible in this regard. Most computers that have an RGB output also have a composite video output.

The resolution of color monitors is generally less than that of monochrome monitors. Composite-video color monitors typically have horizontal resolution in the range of 300 to 500 lines, while RGB monitors range from 500 up to 700 lines. For comparision, a typical color television has a resolution of 250 lines and the new component video monitors, such as the Sony Profeel, have resolution of 350 to 400 lines.

Another specification you will often see for RGB monitors is the dot pitch. This is the center-to-center distance between adjacent dots on the screen and is usually given in millimeters (mm). A smaller dot pitch is better because it means the display will be sharper. The dot pitch is typically between .3 mm and .5 mm.

A color monitor can produce very impressive graphic displays of data, but because of its limited resolution it is not very good for display of text. The highest quality RGB monitors are usable for applications like word processing which require 80-column display of text, but even they are noticeably fuzzier than the best monochrome displays. A composite-video color monitor is not usable for 80-column text display.

Video Signal Standards

Different parts of the world use different standards for the generation of composite video signals (this does not apply to RGB signals). Unfortunately these standards are not compatible with each other. The United States uses the NTSC (National Television System Committee) standard, while most of Europe uses the PAL (Phase

Alternation Line) standard and France and Eastern Europe use the SECAM (Systeme Electronique Couleur Avec Memoire) standard.

The computers and monitors sold within a particular country must adhere to that country's video standard, so if you buy a computer and monitor in the same country they should be compatible with each other. If you buy them in different countries you should make sure that they use the same video standard or they will not work together. Note that this issue is concerned only with the signal the computer sends to the monitor and is totally separate from the question of electrical power supply compatibility.

Recommendations

You should buy a computer with a standard-size display screen, 24 lines by 80 characters, with an anti-glare coating. The screen should be separate from the keyboard so these two critical components can be placed in locations that are comfortable for you. If it is to be used primarily for word processing, you should look for easy-to-read characters. If graphics or color are important to you it may limit your choice of computer. Most CP/M-80-based computers, for example, have neither of these capabilities.

If you get a monochrome display, green or amber is preferable to white. A color display is best used as a second monitor, where the primary monitor is a monochrome one and the color one is used only when required. A high-quality RGB display may be good enough to serve as your only monitor, but for word processing even that is questionable.

TERMINALS

The preceding discussions of keyboards and displays is applicable to most of the popular, single-user microcomputers. It describes a setup where the keyboard and the display are independently connected to the CPU board. They may or may not be physically separate, but each has its own distinct electrical connection. The type of signal sent from the keyboard to the computer is very different from the signal sent from the computer to the display.

There is another configuration that you should be familiar with, because it is used by a few manufacturers, expecially those making CP/M-based machines. The approach uses a terminal (also known as a VDT (visual display terminal) or ASCII terminal) which includes both a keyboard and a display. These two parts are often physically separate from each other, but they share an electrical connection to the computer. This connection is in the form of an RS-232 serial interface (described under PRINTERS - Type of Interface).

The distinction between these two arrangements requires some technical knowledge of the different types of signals involved, a topic which is too involved to cover here. Some computer owners probably don't know which type they have and it is not always easy to tell from a casual glance at an unfamiliar computer. Someone who knows the difference can easily tell from looking at which components are connected together and what kinds of cables and plugs are used. Some of the better known microcomputers that use a VDT are the North Star Horizon and the Morrow Micro Decision. In addition, virtually all computers that use the S-100 bus design require a terminal. The Heath H89 (and the equivalent Zenith Z89) is an interesting design because it consists of a terminal (sold separately as the H19) with a computer and disk drive incorporated into its cabinet.

All of the information in the section on keyboards can be applied to terminals as well, but the information on displays is not entirely applicable. A computer that uses a terminal will not have a video display board. It will not provide a video signal, so the material on composite and RGB signals as well as that on video signal standards is not relevant. Standard terminals generally do not have screen graphics or color capabilities.

PRINTERS

The choice of a printer is in some ways independent of your choice of the rest of your microcomputer system. Very few manufacturers include a printer in a standard microcomputer system. While many computer makers do sell one or more printers, they are always optional additions to the system. The majority of printers sold for microcomputers come from independent manufacturers who specialize in printers. There is tremendous competition in the way of price, performance, reliability, and features. These printers will work with almost any computer and offer tremendous value for the money. Do not feel that just because you bought a computer from one company, that you have to buy a printer from that same company.

Printing Method - Impact or Non-Impact

Most printers produce an image the way a typewriter does, by pressing an inked ribbon against the page, leaving ink in the desired pattern. This is known as impact printing. The major disadvantage that impact printers have is a somewhat high noise level, but there are ways to control this if it is a problem. The majority of printers sold for microcomputers are of this type.

There are five non-impact printing methods: laser, electrographic, thermal, thermal transfer, and ink jet. Laser printers produce extremely high quality output, but they are very expensive ($10,000 and up). Electrographic printers require special paper and do not produce very good print. There are very few manufacturers making either of these types of printers.

Thermal printing uses special heat-sensitive paper that is expensive and may be hard to get in developing countries. The print quality is generally not very good and the paper darkens with age until it becomes unreadable. Many thermal printers do have the advantage of being compact and lightweight and some can operate on batteries. If you have an application that requires portability, this may be a significant advantage.

Thermal-transfer printing is very similar except that it uses plain paper and a special ribbon. The ribbon is coated with a waxy type of ink, which is transferred to the paper by a heated printhead. In contrast with thermal printing, this can produce high-quality, long-lasting documents. A lot of development is going on in this area right now, but not many printers are on the market. Some of those will work properly only with very high-quality paper, producing unsatisfactory results with less expensive paper. Price and availability of the ribbons is likely to be a problem as well.

Ink-jet printers spray or shoot ink onto the paper through a tiny nozzle. This gives very high quality results and is probably the most promising technology for the future. In the last year, prices for this type of printer have dropped drastically. At least two manufacturers, Olivetti and Canon, have announced ink-jet printers for under $1000, and Diablo and Siemens have models for less than $2000.

In spite of some of the advantages of non-impact printing methods, there are no well established, reliable, high-performance printers of this type available now. The best choice for an administrative or research project in a developing country is an impact printer, so the remainder of this discussion will be limited to this type.

Character Formation - Fully-Formed or Dot-Matrix

Impact printers use two different methods of forming characters on the page. One is much like a conventional typewriter in that the printer will have a large number of print heads, each in the form of one of the characters that can be printed. The characters are all part of a single element which rotates. To print, the proper character is brought into position and then struck against the ribbon.

Most of these printers are of the "daisywheel" type, where the element is in the shape of a flat disc with the characters arranged on radial arms around its outer circumference. The overall diameter of the wheel is about 3 inches. At least one manufacturer, NEC, uses "thimbles" in their printers. These elements look like a daisywheel with the outer ends of all of its arms bent up so that its shape is much like a very large thimble.

These printers are often referred to as "letter-quality" printers because their printing is indistinguishable from that of a typewriter. They are more technically known as "fully-formed-character" printers or just "character" printers, because each motion of the printer prints one character, no more and no less.

The other method of forming characters is by use of a dot matrix. Printers of this type have a single print head containing one or more vertical columns of small pins, each of which can print a single dot on the page. The most basic models have a single column of 7 pins. The pins are all controlled individually and characters are formed as "designs" made up of dots. The head prints some combination of dots in one position, moves a small distance to the right, prints another combination of dots, etc.

The density of print is often described by the number of dots making up the width and height of a single character position. A 5 X 7 matrix, for example, means a character may have up to 5 dots horizontally and 7 dots vertically. A 7 X 9 matrix is more typical of today's printers and will give better detail and more readable characters. The best dot-matrix printers have densities of 13 X 18 or more.

The print quality of dot-matrix printers varies over a wide range. The lowest quality ones do not even print some lower case letters correctly, because they cannot print descenders (the portion of a, j, p, q, or y that extends below the other letters). Instead, they shift these letters up into line with the rest of the letters, making the print less legible. Any printer that is restricted to printing in a simple matrix may be unsatisfactory because the dots that make up the characters are noticeable even to a casual reader.

The more expensive dot-matrix printers are capable of overlapping the dots either horizontally, by making smaller steps when moving the print head, or vertically by printing over the same line twice with the print head shifted down slightly. Some of these have print heads with up to 24 pins in two or more staggered columns so they can do overlapping print in one pass. The print quality using these methods is much denser and is often referred to as "memo-quality" or "correspondence-quality". Some of these are almost indistinguishable from typewriter printing.

The extra speed and flexibility of the better dot-matrix printers makes them the best choice for all but the most formal word-processing applications, where nothing less than typewriter quality print may be acceptable.

Speed

Printer speeds are measured in characters per second (sometimes abbreviated to cps). Speeds vary widely, with dot-matrix printers almost always being faster than character printers. It is usually true that within each type of printer, speed increases with price.

Character printer speeds start at about 10 cps and range up to about 55 cps. They usually operate at a single speed regardless of what they are printing. Boldface printing, which requires them to print a character twice with the second printing shifted very slightly in position, will cut their normal printing speed in half, as will underlining.

Dot-matrix print speeds cover a wider range, from 30 cps to 350 cps. Each printer may operate at several different speeds, with higher quality print usually resulting in slower speeds, because more dots are printed per character. The high-speed modes from 150 cps upward are often referred to as "draft quality".

When printing actual documents printers will never achieve their quoted print speeds. Those quoted speeds measure how fast the printer can print characters within a line. They do not account for how fast the carriage can advance the paper (its slew rate) or how fast the print head can move across non-printing positions. You should expect actual printing speeds to be one-half to three-quarters of the quoted speeds.

If you compare these printing speeds with the typing speed of a secretary you may conclude that even the slow ones are quite fast. For example 10 cps works out to about 100 words per minute, which is a very fast typist. In practice you will find that 10 cps is excruciatingly slow, especially if you are the one sitting at the machine waiting for it to finish. It is highly recommended that you choose a fast printer, at least 30 cps for a character printer or 80 cps for a dot-matrix printer.

Paper Feed Method

Printers have two different ways of feeding paper, usually known as friction feed and tractor feed. Friction feed uses a rubber platen like a typewriter. It is used for printing on single sheets of paper, like letterhead or envelopes. If the friction feed is strong enough, it can be used to print on rolls of paper, which may be easier to obtain and cheaper than perforated continuous forms. Tractor feed, also known as pin feed or sprocket feed, pulls the paper through by means of sprockets that fit into matching holes on the sides of the paper. It is used for printing on perforated continuous forms, also known as fan-fold paper because of the way the sheets fold back and forth in the box.

For most purposes tractor feed is more convenient because it allows you to print long reports without having to feed in individual sheets of paper. However it will not work with any paper that does not have sprocket holes, so you will probably have a need for friction feed as well. A friction-feed printer can print long reports on rolls of paper, but the resulting printouts are cumbersome to handle in rolled form and are a nuisance to fold or cut up. Many printers are capable of both methods and can be switched from one to the other quickly and easily. It is recommended that you choose a printer that has both friction and tractor feed.

Most tractor feed mechanisms can be adjusted to handle forms that are as narrow as 2 inches. This capability may be important for such things as printing mailing labels. Some machines that have both friction and pin feed accomplish this by adding the pins at the outer ends of a nonremovable platen. This provides pin feed for full-size paper only, although you may be able to buy a fully adjustable tractor mechanism as an option.

Some friction feed printers have optional automatic feeders that accept a stack of single sheets, feeding them into the platen one after the other. For a job like printing large numbers of form letters these can save a great deal of operator time. Unfortunately, the feeders are very expensive, costing as much or more than the printer itself, and may require frequent maintenance to work smoothly.

Paper Width

Printers come in two standard carriage widths - one that will handle paper up to 14" (36 cm.) wide, the other limited to 8.5" (22 cm.). This is the width of the paper that is actually printed on; if tractor feed is used the sprocket holes add another .5" to each side for a total width of 9.5" (24 cm.) or 15" (38 cm.). Printing at the normal 10 characters per inch (cpi) these will accomodate either 80 or 136 characters per line.

The wide-carriage printers tend to cost several hundred dollars more than the standard ones. They are most useful if you will be printing a lot of reports or data summaries which can't easily fit into 80 columns. However, most dot-matrix printers offer one or more compressed-character modes which will fit up to 136 characters on 8.5" paper. The legibility suffers slightly, but if you only have the need for this occasionally it may do an adequate job.

Buffer Size

A microcomputer can send information to the printer much faster than the printer can print it. To cope with this problem, printers have built into them a certain amount of RAM just like that inside the microcomputer. This printer memory is usually referred to as a buffer.

As the computer sends information out, the printer stores it in its buffer. When the buffer is full, the printer signals this to the computer and the computer will stop sending. The printer then prints what is in the buffer and when it finishes, signals the computer to start sending again.

The reason this is significant is that if the entire document to be printed will fit into the print buffer, the computer will send it very quickly and will have nothing left to do. As far as it knows, the printing will be finished and it can go ahead and do other things like running another program. Meanwhile the printer will be printing from its buffer. Note that it does not speed up the printer significantly; something that takes an hour to print will still take almost that long. What it does is to allow you to use the computer for other things while the printer is printing.

Naturally the bigger the buffer, the more valuable it is. On the other hand, the extra memory costs money. If you never print more than one-page letters, a huge buffer would be a waste of money. Printer buffers range in size from about 80 bytes (one line of print) up to 4K bytes. A double-spaced page of text contains about 1800 characters, so a 4K buffer would hold just over two pages. Most printers come with a fixed-size buffer, but some give you a choice of two or three different sizes.

There are also accessory buffers available from many manufacturers that connect between your computer and printer. These have buffers ranging from 8K bytes to 512K bytes with prices starting at about $150. If you need to print large documents and can't afford to have your computer tied up while the printing is going on, these might be a very good investment. If you buy one, be sure it will work with your computer and printer. You will have to specify your model of computer and printer as well as the type of interface between them (see the following item).

With the appropriate software, some computers can use part of their internal memory as a printer buffer, allowing printing and some other activity to go on at the same time. This approach (known as print spooling) requires some work from the microprocessor throughout the printing process, so it may slow down the operation of the other program you are trying to run. This problem does not occur with an external buffer.

Type of Interface

There are two different ways that the computer and printer can communicate with each other. This is referred to as their type of interface. A parallel interface sends one entire character (8 bits) to the printer at one time. This character is sent on 8 separate wires which are "parallel" to each other, hence the name. A serial interface sends only one bit at a time using a single wire. Each character is sent as a "series" of eight bits.

There are three specific names for interfaces that you should be aware of. The most common type of parallel interface was designed by the Centronics Corp., a manufacturer of printers, so it is often called a Centronics interface. Another kind of parallel interface is the IEEE 488, named after the Institute of Electrical and Electronic Engineers, the developer of the design. The most common type of serial interface is called an EIA RS-232-C (or sometimes just RS-232) interface because it is based on a standard developed by the Electronics Industry Association.

Your computer may come with either a serial or parallel interface as standard or it may have neither or both. (An interface may be referred to by other names, such as board, card, adapter, port, etc.) Your printer may come with either or both or you may be able to order it any way you want it. The computer and printer must have the same type of interface in order to work together.

A parallel interface is usually slightly cheaper than a serial interface and tends to be easier to set up and use. There are a large number of parameters associated with a serial interface that must have exactly the same settings on the printer and the computer in order for the two to work together. Many word processing programs have to be "told" these settings before they can send anything to the printer. These steps are not necessary with a parallel interface. If you have a choice, use a parallel interface.

With either type of interface, you must make sure that you get the correct cable to connect the printer and computer. If the printer comes with a cable, do not assume that that cable will work with your computer. If you are buying your whole systems from one source, specify that you need a cable for your particular combination of computer and printer. If you get the printer from a different source than the computer, it is usually easier to get the proper cable from the printer supplier than from the computer supplier. If you tell them what kind of computer you will be using they can usually supply an appropriate cable.

Character Sets

Computers use a set of code numbers known as ASCII (American Standard Code for Information Interchange) codes for internal representation of data and for communication with devices such as printers. The ASCII codes range from 0 up to 127. Thirty-four of these are used for what are called non-printing characters, such as carriage return, line feed, space, and backspace. The printing characters consist of the upper- and lower-case alphabet, ten digits, and the following 32 special characters:

! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [\ ] ^ _ ' { : } ~

If these characters alone will serve your needs then virtually any computer/software/printer combination will have complete character compatibility. Many printers provide additional special characters which may be quite useful when doing word processing in a language other than English or when mathematical notation is needed. If you want to use any of these non-standard symbols, you will have to make sure that your computer and your software are capable of sending them to the printer.

Dot-matrix printers will usually provide additional special characters by using an "extended ASCII" character set. This will use the codes from 128 up to 255 to represent the additional characters. Unfortunately there is no standard for these codes, so each manufacturer defines them differently and some don't provide for them at all. Some computers have no way of generating ASCII codes between 128 and 255 from the keyboard and some software will not recognize them if they are generated. If either of these is true, the extra characters on the printer are useless to you. There can even be a further problem. The computer display may have different definitions for those codes than the printer does or it may have no definitions at all. This would mean that even if you could type them in from the keyboard and your software would accept them, the display might show them as blanks or as some other character. This in itself does not prevent you from printing them, but it can be confusing because what is printed is different than what is on the screen.

Some dot-matrix printers have several different switch-selectable character sets. These usually substitute common symbols from alternative languages for less-commonly-used ASCII symbols, such as, ^, (, and). Thus a printer may have alternative character sets designated as French, German, and Spanish.

Some of the most recent dot-matrix printers allow for "downloadable" character sets. This means you can use your computer to design the dot-matrix pattern for any characters you need and then send (download) your own character set to the printer. The printer stores your patterns (characters) in special memory locations and lets you print documents using them. This allows an incredible degree of flexibility but it does require more work and knowledge from the user. Note that this new character set is defined only for the printer, so your display will continue to use its own standard character set. This means you will have the problem described above, where the display will show something different than what is printed.

Character printers are, of course, limited to printing the characters that are on their printwheels. Most daisy-wheel printers have 96 characters on each print wheel, with one character on each spoke (or petal). Thimble printers have fewer arms but put two characters on each arm for a total of 96 to 120 characters. A 96-character wheel has 34 positions for special characters, which is two more than the ASCII character set has. A 120-character thimble has 26 more than the ASCII definitions. These extra characters are handled by redefining some of the non-printing ASCII codes, which means the display will show something different than what is printed. Since the printwheels are replaceable you can choose from different character sets as well as different type faces. However, it often happens that the characters you need are not all available on one wheel. This requires the printing to stop when the appropriate character is reached (some word processing programs provide for this). The operator must change the wheel in the printer, the computer will print the character and then wait for the wheel to be changed back again. This is obviously too time-consuming to be done very often, so don't count on the replacement of printwheels to provide you with a larger character set.

It is worth repeating here that if the standard ASCII character set reproduced above is enough for your work, you will not have to worry about all these intricacies. If you want to use other characters, make sure that your computer and software, as well as your printer, can handle them.

Graphics and Spacing

One major difference between character printers and dot-matrix printers can be found in their ability to print graphics. Character printers are usually limited to printing the characters that are on their print wheels, whereas a dot-matrix printer that is sophisticated enough can print any kind of pattern of dots anywhere on the page. There are some character printers that have a graphics mode where they can use their "period" character to do plotting, but they are extremely slow when doing this. If you want to do any significant amount of plotting or other graphics you should buy a dot-matrix printer.

Character printers offer three standard character spacings: 10 characters per inch (cpi), 12 cpi, and proportional. The 10 and 12 cpi spacings are the standard spacings offered on typewriters and are often referred to as 10 pitch or 12 pitch, or pica and elite, respectively. With these spacings each character position takes up the same amount of room on the line whether it contains a narrow letter like an i or a wide letter such as an m. This tends to make some characters look crowded together and others to look spaced apart. Proportional spacing allots each character just the amount of room it needs so that the gaps between them are uniform. This produces documents that look better and are easier to read.

The lowest priced character printers offer a choice of 10 cpi or 12 cpi but not both. A little more money will get you printers that let you switch between 10 cpi and 12 cpi. The best character printers also include proportional spacing.

Dot-matrix printers typically offer many more choices of character spacings, from 5 cpi to 20 cpi as well as proportional print of several sizes. The lowest priced models won't have all of these, but medium to high priced ones will.

Another capability offered on better models of both dot-matrix and character printers is subscripting and superscripting. These, as well as graphics and all the different spacings described above, are usually activated by special commands sent to the printer by the software. All printers use different commands which raises the issue of compatibility, discussed in the next section.

Compatibility

It was stated above that almost any printer will work with any computer. This is true as far as the hardware goes, but you have to be careful when it comes to software.

If you are only doing what might be described as data processing (running BASIC programs, using a spreadsheet package, doing statistical analysis, etc.) you shouldn't have any problems. If you are doing anything in the area of graphics or word processing you will have to make sure that your printer is compatible with your software.

Different brands of printers require different commands in order to carry out their special functions like bold printing, subscripting, or proportional spacing. These differences between printers make it difficult for a particular word processing package to work with all printers. The designers of a package will usually select a few common brands to set up their package for. You should look at the documentation to be sure that the software is compatible with your printer. Better yet, you should have the dealer demonstrate the package on your computer and your printer. It is very risky to take a dealer's word that a particular combination will work together.

Many graphics or word processing programs are distributed in a version set up for a particular printer, but they also provide a separate "installation" program that will modify some of the characteristics of the package to work with other printers. If your printer is one of the alternate models provided for by name in the installation program it is a simple matter to use the program. If the installation program claims to allow you to adapt the package for any printer and yours is not specifically named, you should be very wary. This will almost certainly require quite a bit of technical knowledge, more than even some programmers have. If you do not have someone capable of dealing with such matters, don't buy such a package unless the dealer will guarantee to set it up for you or refund your money if he can't.

Sometimes compatibility between a particular program and a printer is achieved by use of a special interface board to connect the printer and computer. In this case the description of the program will say something like "requires Epson printer and Grappler interface". If you have the Epson printer with a different kind of interface, the program will not work.

The issue of compatibility between printers and software is one example of why it is best to find the software you need first, then buy the hardware that will run it. If you buy the printer first because, say, you can get a really good deal on it, you may later find that you are limited in your choice of packages that will work on it.

Printer Switches

Most printers include switches which allow you to choose some of their printing characteristics. The selectable characteristics may include such things as number of characters per inch, the quality of the print (usually affecting the speed as well), and the type of interface. They may also include some other characteristics such as whether the printer will automatically go to a new line when it receives a carriage return and whether it will leave a few blank lines at the top and bottom of each page of continuous forms paper.

You may find it necessary to change some of these settings often, depending on what program you are using or what you are printing. On most printers it is possible to send control codes from the computer that will override the switch settings, but it is often easier to change the switch itself. Unfortunately, many manufacturers put their switches in very inaccessible locations, apparently assuming that you will set them once and leave them. In the worst cases it is necessary to turn the printer upside down and remove screws holding the case together in order to get to the switches. Readily accessible switches make a printer much easier to use. A few printers, such as those by MPI and Mannesmann-Tally, have front-panel keypads that allow you to quickly and easily change any of their printing characteristics.

Replacement Parts

There are two parts of a printer that you are likely to have to replace - the ribbon and the printhead or printwheel. Ribbon replacement is likely to be quite frequent if you use the printer heavily. You can use up a ribbon in a week of heavy printing. Most computer printers use some type of cartridge ribbon that snaps in and out easily, costs $8 to $15, and has a rated life of 300,000 to

5,000,000 characters. Before buying a printer you should make sure that the appropriate kind of ribbon will be readily available in your area. Some printers, such as those by Okidata, use standard typewriter ribbons, which are much cheaper than the special cartridge ribbons and are easier to obtain in developing countries.

An alternative to buying replacement ribbons is to get a re-inking device. These sell for $50 to $100 and are available for many of the most popular types of printers. They put a new coating of ink on a used ribbon allowing it to be used until the ribbon itself begins to wear out. If you use one of these, be sure to use only ink that is recommended by the manufacturer or you may make the ribbon unusable. For dot-matrix printers it is especially important that you use the right ink, because the dot-matrix printhead requires an ink containing a lubricant. If you use the wrong kind of ink, the printhead may be seriously damaged.

Barring that kind of damage a dot-matrix printhead will last a very long time. They are typically rated to print 100,000,000 characters or more. Nevertheless, you should be prepared for yours to fail at the worst possible moment. It would be wise to buy a replacement head at the time you buy the printer unless you have a dealer you think you can rely on to have one in stock when you need it. A printhead will cost roughly $50.

The printwheel for a character printer will not last as long but it also costs less to replace. A plastic daisywheel costs about $8 and will usually print each character 1,000,000 times. Plastic thimbles cost about $15 and are rated at 30,000,000 impressions per character. Metal daisywheels, used in Xerox and Diablo printers, cost about $60 and usually give slightly cleaner looking print as well as longer life. You should be sure to keep several extra printwheels on hand.

COMPUTER-TO-COMPUTER COMMUNICATIONS

When it is necessary to transfer files between two microcomputers or between a microcomputer and a mainframe, the preferred transfer method is floppy disk. Unfortunately this requires that the two computers have a common disk format. If they do not, you must make an electrical communication link between the two machines and transfer the file over that link.

There are two common methods of doing this. Both methods require that the two machines have an RS232 serial interface as well as communications software. The simpler method can be used if the two computers are physically close to each other (in the same room, for example). It involves connecting a cable between the serial interfaces of the two machines and then sending the files via that cable. The second method can be used if the two machines are some distance from each other but each of them is close to a telephone. It requires two additional pieces of hardware called modems (an abbreviation for modulator/demodulator) and cables to attach each modem to the serial interface in one of the computers. This method is almost always used if one of the computers is a mainframe.

Inter-computer communications is probably the most complicated computer-related subject that the average computer user will ever deal with. There are dozens of factors involved in communications, including switch settings, cable wiring, software settings, file formats, and operating system characteristics, all of which must be correct for the transfer to work properly. If the transfer does not work, it can be very difficult to determine where the problem lies. Further complicating matters is the fact that different manuals use different terminology for the same characteristic.

This is such a technical subject and there are so many variations in it for each specific case, that it is very difficult to give a short, general overview of the subject that is of much practical value. For this reason we hope to publish a separate paper on this topic at a later date. There is one book listed in the "Recommended Reading" that is specifically about communications and can get you started on the subject. My best advice at this time is that if you need this kind of communications capability, get the services of someone who knows the subject quite well and who can look at your specific needs.

POWER REQUIREMENTS

Many development projects have found that their biggest problems with microcomputer equipment have been related to power requirements. Foreign voltage levels and frequencies may make it difficult to find appropriate equipment, especially if that equipment is to be purchased in the U.S. Once the computer is in use, unreliable local power systems may cause momentary shutdowns resulting in loss of data or even damage to the equipment. Selection of a microcomputer must take these factors into account.

Voltage and Frequency

In the U.S., AC (alternating current) power is supplied at 110 volts, 60 Hertz (Hz). Other countries have different voltages and frequencies, with the most common combination being 220 volts and 50 Hz. If you buy equipment in the country where it is to be used, this should be of no concern to you. If not, you must make sure that differing power sources can be accomodated.

Some equipment has switchable power supplies that will operate on either 110 V 60 Hz or 220 V 50 Hz. The conversion is done by means of a switch or a movable jumper wire, often inside the cabinet. Other components may be special-ordered in a version that has the proper power requirements. Another common situation is that the component may be frequency-insensitive, allowing it to run on either 50 or 60 Hz. In this case a step-down transformer will be needed to convert a voltage of 220 to 110.

It is best to be very cautious about taking a salesman's word about the power supply requirements of a particular unit. This is a subject that most sales people know almost nothing about, yet they may be quite willing to assure you that it is no problem. If you have access to any of the equipment you are thinking of buying, you can check the power requirements yourself. There will be a label on the equipment, near where the power cord enters the cabinet, specifying the voltage and frequency. If you can get a copy of the owner's manual or some manufacturer's literature it should include this information as well.

If you have to order some of your equipment, because you have no local dealer or the dealer is out of stock, be sure that any special power requirements are written into the order. For example, you could specify: "Epson FX-80 printer (50/60 Hz model)", or "Amdek 300 G monitor (switchable for 110V, 60 Hz and 220 V, 50 Hz)". You should do this even if someone has told you that the power supply you need is a standard feature on that piece of equipment. This gives you some protection if, say, a distributor has some older pieces in stock that do not fit your needs.

Power System Problems

The power available from a wall outlet is supposed to be a constant voltage, say 220 volts, at a single, steady frequency, say 50 Hz. Unfortunately, this is rarely the case even in the U.S. while in developing countries, the power systems tend to be even more unreliable. This can cause tremendous problems in the operation of a computer.

Two kinds of power disturbances that are familiar to most people are the blackout and the brownout. The blackout is a power failure, which might last minutes or days. It can be caused by a storm, a broken cable, a power station failure, or many other occurences. There may also be momentary blackouts sometimes called glitches, lasting only a fraction of a second, barely long enough to even dim the lights. These are usually caused by faults in the power system itself. A brownout is a temporary reduction in the voltage during times of extremely high demand. A voltage that is nominally 110 might be reduced to 90 volts. A brownout will usually last a few minutes to a few hours. In an area that has a very marginal power supply, a brownout might be the normal condition, with voltages always 10 to 20 percent below what they are supposed to be. A brownout of a few seconds, known as a dip or sag, may be caused by a large piece of equipment, such as an air conditioner or elevator, turning on.

There are also two kinds of excess voltage conditions that most people are not familiar with because they have little effect on most electrical equipment. A voltage spike is a very sharp, momentary voltage increase. It lasts a small fraction of a second and the voltage typically reaches two to ten times its nominal value. It may be caused by something like a nearby lightning strike. A voltage surge is a longer-term voltage increase of lower magnitude than a spike. A surge might cause voltage to rise 50% for several seconds and can be caused by such events as a large motor or compresssor turning off.

One more potential power problem is electrical noise. This does not affect the basic voltage delivered very much, but it adds high frequency components to it. You might think of this as something like static on the line. This is usually caused by nearby electrical components which emit high frequency radiation or which make and break electrical contacts (motors, for example).

Potential Types of Damage

Power system problems can have many different effects on a computer. These effects fall into three general categories, which differ primarily in severity.

1. Interruption of Work

This is the least damaging result from a power problem. It can include such things as interruption of a running program (necessitating a restart of the computer or the program), loss of any data or intermediate results that have not yet been stored on disk, modification of programs or data stored in RAM, or modification of the screen display. The recovery from such a problem might be as simple as restarting a program or as difficult as re-entering information that had been typed in but not saved to disk. It is conceivable that the output of a program could be affected without the user being aware of it, but this is highly unlikely.

2. Loss of Data on Disk

This can happen two ways. If the disk drive is writing on disk when a power disturbance accurs it is quite likely that the file that was being written will be damaged. If the disk directory was being written, it is likely that some or all of the files on the disk will be made unusable. Even if the drive is not in the act of writing it is possible to lose a file. In some cases, if a program has made some changes to a file and gets interrupted before it has "closed" the file, the file may be made unusable. The possibility of damage to disk files is a major reason for maintaining backup copies of files.

3. Damage to the Computer

It is quite possible for voltage spikes and surges to burn out electronic components. A power failure may cause a "head crash" on a hard disk drive, which can damage the head as well as the disk. These are probably the most catastrophic results of power problems because they cost money and time to repair.

Types of Protection

There are many different power conditioning devices available from about $50 to $2000. Some of them protect against one specific type of power problem; others provide protection against almost any kind of occurence. Some of them provide multiple outlets so that you can plug in all of your equipment without getting a separate multiple outlet strip. An on/off switch that controls the outlets is usually a desirable feature because it allows you to leave all of the individual components switched on and turn them all on or off with one switch.

For any type of power conditioning device it is important to know how much power it will be required to handle. This is expressed in watts (W) or volt-amperes (VA), which are essentially equivalent units. The total power required is simply the sum of the power required by each of the devices you will be using. A typical microcomputer system will require 200 to 500 watts. It is cheaper to buy one high capacity unit than two smaller ones, so if you expect to add more components to your system, buy a power conditioner that will handle all of them.

1. Isolation Devices

These keep unwanted disturbances on the power line from reaching the computer. Spike/surge suppressors, as the name implies, protect against voltage spikes and surges. A 110 volt model will usually have a clamping voltage (the maximum voltage it will let through) of 200 volts. This may sound rather high, but for spikes or quick surges, that kind of voltage should do no damage.

Noise filters keep static and other kinds of noise out of the power line. They will usually specify a frequency range over which they are effective. This might be something like 10 kHz to 300 MHz. A wider range is better than a narrow one.

These isolation devices cost about $50 to $200 and are a very wise investment, even for a computer to be used in the U.S. The spike/surge protector in particular gives good protection against something that could easily cause costly damage to your computer.

2. Voltage Regulators

A voltage regulator will keep the voltage supplied to the computer within a specified range, even if the wall voltage varies considerably. It will usually have maximum permissible input voltage and output voltage variations specified. A common specification is that input voltages varying up to 15% will be regulated to give an output voltage within 3% of the required value. As you can see from that specification, voltage regulators are not designed to cope with severe overvoltages, like spikes, or severe undervoltages, like blackouts. They can sometimes be found combined with spike/surge suppressors for extra protection. Voltage regulators typically cost $300 to $500.

3. Uninterruptible Power Supplies

These devices, often called UPS's, are the only ones which provide protection against blackouts and severe brownouts. They typically cost $500 to $2000.

The forward-transfer (or standby) type of UPS operates the computer from the line power as long as it is at an acceptable level, but switches to a battery for power if a low voltage condition develops. The battery is built into the UPS and is kept fully charged. The switch to battery power is typically done within one-half cycle (1/120 second for 60 Hz) and a warning light indicates this to the computer user. The battery can usually run the computer for 5 to 20 minutes, giving you time to complete any operation currently in progress, save data to disk and shut the computer off without damage.

There is another type of UPS known as continuous-service. This has a battery that is always in use, being charged from the main power, with its output being converted to AC to run the computer. In some ways this is simpler because the circuitry to switch instantaneously to battery power is unnecessary. It has the advantage of providing inherently excellent isolation from variations in the power system, such as spikes and noise. A continuous service UPS is usually larger than a standby UPS and costs more because the battery and charger must have a higher capacity.

The power supplied by a utility company is always in the form of a sine wave. An inverter, the device that converts battery power (DC) into AC, usually puts out a square or rectangular wave. Some computers will not run properly on this kind of power, with overheating being a common result. This is not much of a problem with a standby UPS, because the computer will only use the battery power for a few minutes until you can shut it off or the power is restored. If you are considering the use of a continuous-service UPS, you should check with the manufacturer of your computer to verify that it can run on a rectangular-wave power supply.

Recommendations

Electrical utility systems in developing countries have a reputation for being highly unreliable. Power disturbances can be very frustrating, time-consuming, and costly when they affect your computer system. Under these circumstances you should not even consider using a microcomputer without some form of power conditioning.

Under the best circumstances, a spike/surge suppressor may be sufficient. If the line voltage is consistently low or there are frequent sags in the voltage, a regulator should be used in addition. For most circumstances this is probably the best combination. If blackouts are common or if continuous use of the computer is absolutely crucial to your work, only a UPS of some kind will be enough.

There are quite a few U.S. companies producing UPS's and other power conditioning devices, most of them intended for mini and mainframe computers. Many of them do produce models that are appropriate for microcomputers and are available for different line voltages and frequencies. Since the sources of these products are not well known, I am including the addresses of five companies that make UPS's for microcomputers. Two of the most readily available models in the U.S. are the Cuesta Datasaver and the Sola Mini UPS. In their 60Hz, 110 volt versions they cost approximately $700 and $1500 respectively. The Cuesta is rated at 200 watts, while the Sola is rated at 400 watts and has slightly better specifications. You can get more details about all of the products available by contacting the following manufacturers.

Cuesta Systems, Inc.
3440 Roberts Court
San Luis Obispo, CA 93401
(805) 541-4160

Gould
2727 Kurtz St.
San Diego, CA 92110
(714) 291-4211

Elgar Corp.
8225 Mercury Ct.
San Diego, CA 92111
(714) 565-115

Sola Electric
1717 Busse Rd.
Elk Grove, IL 60007
(312) 439-2800

Franklin Electric
995 Benicia Ave.
Sunnyvale, CA 94806
(408) 245-8900

RECOMMENDED READING

Along with the explosion in microcomputer hardware and software has come an explosion in publications about microcomputers. Unfortunately, the majority of books about microcomputers are not of very high quality. They tend to be superficial, out-of-date, technically inaccurate, incomplete, or all of the above. Some of them contain information or advice that is just plain wrong.

The books recommended here, while they all have weaknesses, are the best that the author has seen. Unfortunately none of them are specifically intended for researchers; they are aimed at either the home computer user or the business computer user.

The first five are all general introductions to microcomputers. None of them has as extensive a section on hardware as this paper, but they cover many topics not included here, such as where a computer is the appropriate tool, operating systems and software, etc. There is another book available from the first author, McWilliams, called The Personal Computer Book, which includes much of the same material but has more coverage of home computers and less coverage of business topics.

The sixth book in the list deals specifically with communications. About 80% of it is devoted to use of the various electronic information services available in the U.S. The remainder of the book covers more general communication topics that will be useful to readers of this paper.

The seventh book, DON'T!, gives useful information on the setup, use, and care of a small computer, some of which cannot be found in most other books. The last book, Crash Course, is included here for the person who wants to learn more about the technical aspects of microcomputers. It is a programmed text that comprises an introductory course in microcomputers.

1. The Personal Computer In Business Book
   Peter McWilliams
   Prelude Press, 1983

2. What Do You Do After You Plug It In?
   William Barden Jr.
   Howard Sams, 1983

3. How To Buy a Personal Computer
   Carlton Shrum
   Alfred, 1981

4. A Practical Guide to Small Computers
   Robert Rinder
   Simon and Shuster, 1981

5. So You Are Thinking About A Small Business Computer
   R.G. Canning and N.C. Leeper
   Spectrum, 1982

6. The Complete Handbook of Personal Computer Communications
   Alfred Glossbrenner
   St. Martin's Press, 1983

7. DON'T! Or How To Care For Your Computer
   Rodney Zaks
   Sybex, 1981

8. Crash Course In Microcomputers
   Louis E. Frenzel Jr.
   Sams, 1980

There are a few papers the author is aware of that deal specifically with the use of microcomputers in developing countries. In addition to the topics of hardware and software covered in the books listed above, they also cover such issues as training and institutionalization.

1. Considerations For Use Of Microcomputers In Developing Country Statistical Offices

International Statistical Programs Center
Bureau of the Census
U.S. Department of Commerce, 1983

2. Acquiring and Using Microcomputers in Agricultural Development: A Manager's Guide (Draft Copy)

Marcus Ingle, Noel Berge, Marcia Teisan

Development Project Management Center
Office of International Cooperation and Development
U.S. Department of Agriculture, February 1983