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ABSTRACT

The last few years have seen more and more secondary schools introduce computer concepts and some form of computer resource into their educational program--usually a commercial time-sharing service with a modest initial expenditure--but almost invariably the demand for terminal availability and computer usage suggest the need for alternatives. This report surveys the various means of implementing a computer resource: commercial time-sharing, small-scale time-sharing systems, multi-use minicomputers, and minicomputer systems. Each approach is analyzed for cost, support required, number of students supported. How the students make use of the resource and its educational limitation are also reviewed. The implementation of high level languages, such as FORTRAN and BASIC, are considered for their educational utility and the number of students they can support. In addition, a survey of minicomputers and suitable peripheral equipment is appended. Manufacturers and equipments are named and discussed, and prices are also provided. Finally, a glossary of computer technology jargon is included. (Author/SH)

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FINAL REPORT

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# DEVELOPMENT OF SPECIFICATIONS FOR A LOW COST COMPUTER SYSTEM FOR SECONDARY SCHOOLS

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U.S. DEPARTMENT OF
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SUMMARY

The last few years has seen more and more secondary schools introduce computer concepts and some form of computing resource into their educational program. The usual computing resource introduced into the secondary school is the commercial time-sharing service utilizing telephone lines, data set and a teletypewriter terminal. Commercial time-sharing services are quite satisfactory when the educational program is just beginning, since it requires little prior experience and only a modest expenditure to start up. Almost invariably, however, after a relatively short time the demand for terminal availability and computer usage will out strip the available funds. As the demands for computer service and expenditures increase alternatives to commercial time-sharing services should be considered. These alternatives include small scale time-sharing systems, limited multi-user and single-user minicomputer systems. Each of these approaches has been examined for cost, how the student will use it, and how effectively will it handle large numbers of students.

Minicomputer systems are an attractive alternative costwise, since they are comparable when considering total time-sharing costs, including the terminal and telephone charges over one or two years. The minicomputer, in the educational environment, can provide advantages that a time-sharing service cannot provide. This includes assembly or machine language instruction, "hands-on-the-machine" experience, and a much greater appreciation of what a computer is, how it operates, what it can and cannot do. The minicomputer is quite flexible in the way it can be used. It is quite possible for a secondary school to start with a useful minicomputer system for about $6500 and to expand it, as the needs and demands require, to a sophisticated educational system. Minicomputers, however, use the teletypewriter for input-output, as does time-sharing. Because the teletypewriter is a relatively slow device and because of the manner in which it must be used, it tends to restrict the number of students who can have access to the computer. The modern minicomputer is inherently capable of processing many more student problem programs then the teletypewriter permits. Recent advances in technology have resulted in a number of low cost peripheral input-output devices for use with the minicomputer. Integrating suitable low cost input-output devices with a minicomputer can result in a highly efficient educational computer system. Such computing systems, with a high capacity for processing student programs, can support several hundred students. All of the computer system configurations developed in this report cost below $25,000. They begin with the simplest useful computer system and indicate how it can be expanded to meet increasing demands for computing resources. The use of mark sense cards as an input medium is discussed and its advantages are explored.

The report develops criteria and specifications for selecting a minicomputer and suitable input-output peripheral devices. The configurations developed indicate how these peripheral devices can be utilized to create effective educational computer systems. Although these computer systems are general purpose and can serve in a variety of pedegogical roles, they are not designed with computer aided instruction (CAI) in mind. A fairly thorough survey of minicomputers and suitable peripheral

equipments is included in the appendices. Manufacturers and equipments are named, not as endorsements but as equipment which the author feels is suitable at the time of the report. Prices are also given but should only be taken as guide lines and not as firm quotes. Several pitfalls in planning a computer system are discussed including what the computer manufacturer's salesmen present and what should be considered. Since computer technology has developed its own special vocabulary and jargon, a glossary has been included in the report. The glossary is orientated to those with little or no background in computer technology. It is hoped that the glossary will better equip those who will deal with computer salesmen or use computers in the classroom.

The report describes the various means of implementing a computer resource, ie, commercial time-sharing, small-scale time-sharing systems, multi-use minicomputers and minicomputer systems. Each approach is analyzed for cost, support required (both of the secondary school and vendor), number of students supported. How the students make use of the resource and its educational limitation are also reviewed. The implementation of high level languages, such as Fortran and BASIC are considered for their educational ulility and the number of students they can support. How BASIC can be used in the configurations developed is also indicated.

## Introduction and Background

### I. General

Until recent years, education in the computer sciences has been the domain of colleges and universities. However, secondary school educators have been, for some time, increasingly aware of the growing role of computers in our technology-oriented society. These educators have been anxiously interested in introducing computers, computer concepts and computer related materials into the secondary level curricula. Teachers, particularly in mathematics and the sciences, have pursued course work, inservice programs and summer institutes in order to acquire or expand their working knowledge and abilities with computers and related subjects. Students in the SSTP (Secondary Science Training Program) have been most enthusiastic in their response to computer oriented programs. In some instances it has been these students who have provided the impetus to involve their schools in a computer education program. In addition, a great deal of interest has been aroused and stimulated by a number of the programs funded at the secondary and university levels. Much useful information and curriculum development work has resulted from these programs. As increasing numbers of students participate in the various programs, many of the operational problems are coming to light.

Most programs start with modest ambitions. A relatively small number of students, usually honor students and/or seniors are selected at the start of a program. Either a time-sharing service and terminals or a computer is obtained as a computing resource for the program. So long as the group remains relatively small, the program proceeds fairly well. The inherent limitations of the computer resource, common to most programs, becomes evident as attempts are made to extend the program to broader segments of the school's population. The major limitation then encountered is the number of student problems which can be processed by the available computer resource. When the students are learning the elements of a programming language, such as BASIC,*the size of their computer programs are relatively small. However, they must have repeated access to the computing facility to correct syntactic as well as logic errors in their computing program. The type of computing resource available and how it is managed has an important bearing on how many student problems can be processed. Later in this report I shall describe the common approaches to computing resources, how their limitations manifest themselves, and an alternative solution designed to improve the student problem-program processing limitations. The number of student computer-programs grows quite rapidly as the students begin to explore the use of the computer to solve problems in their other courses and laboratory work. Teachers who did not originally contemplate using the computer in their subjects soon realize the pedagogical value which the computer may afford them. Most educators appreciate the value of permitting students the freedom to explore the world of computers, within appropriate limits. Thus, the demand for computing re-

* BASIC - is a conversational algebraic language developed at Dartmouth College.

sources can easily grow beyong the capacity of the initially chosen resource. This forces the school to limit student access to the computing recource.

It is worthwhile to examine the approaches which secondary schools have taken to obtain a computing resource. We shall also examine student behavior in terms of cost, efficiency and problem throughput and limitation. Finally we shall look at some alternative solutions with relatively high capacity for processing student problems.

In general, two basic approaches are available in securing computer resources for a program in computer education.

## II. Commercial Time-Sharing Services

The first and easiest computer resource to start with, is to use a commercial time-sharing service. Teletypewriter terminals are used in a classroom to communicate with a remotely located computer over ordinary telephone lines. The teletypewriter is a typewriter-like device which can operate at a maximum speed of 10 characters-per-second. A data set (or a coupler) interconnects the teletypewriter and the telephone line to the remote computer site. The student dials the number which will connect him to the time-sharing computer. Using the terminal, the student supplies information which identifies him to the computer as a valid user of the time-sharing service. This initial dialog is usually termed "logging into the system." The student then specifies some additional information, such as which programming language he wishes to use, whether he will enter a new program or modify a previously entered one. At this point the student may actually begin working on his programming problem by typing statements in the programming language. At some point, depending on the time-sharing system employed, the computer will notify the student of syntactic errors in the statements entered. The student must either recognize the error, consult a manual or book, or ask someone for help. Once past all the language errors, the student may still find that his program does not give him the correct answers. This usually indicates a lack of problem understanding on the part of the student. The student may have a clue as to what went wrong or he may seek clarification and assistance from the instructor. Before the student leaves the terminal he is usually required to "log-off the system." For a student to accomplish any meaningful work, he will have to spend a minimum of 20 minutes at the teletypewriter terminal. In general, several sessions at the terminal will be required in order to solve most problems. This time restriction has a natural tendency to restrict the number of students who can have access to the computer resource. The number of terminals can be increased to handle additional students but this raises the question of costs. The costs for operating with timesharing terminals will include the cost of rental of a terminal with a suitable dataset or coupler, supplies, such as paper, paper-tape, in ribbons, telephone line charges, connect-time (i.e. the length of time the terminal is actually connected to the computer), actual computer usage, and use of the computer's storage facility. Actual costs will depend on basic telephone line charges from the terminal to the computer, and on the time-sharing vendor's rate schedule. We can, nevertheless, give the range and typical costs the user might expect to encounter:

| | range | typical |
|---|---|---|
| 1 - Terminal, telephone coupler, supplies and maintenance | $65.00 - $100 | $85.00 per month rental |
| 2 - Telephone and line charges | .60 - 3 | 1.50 per hour |
| 3 - Connect time | 6.00 - 12 | 7.50 per hour |

If the teletypewriter terminal and a time-sharing service is used 4 hours daily, 5 days a week, for a typical school year (9 months) the cost will be about $7,250 per terminal per year. The largest single factor contributing to the cost of operation is the connect-time charges. This can be reduced by seeking educational discounts, bulk usage rates, and "shopping around." It does not take many students to exceed the capacity of a single terminal. It does help to have at least one or two additional teletypewriters which are used solely for the purpose of preparing programs on punched paper-tape. Placing the programs on punched paper-tape is done independently of the remote time-sharing computer. It is analogous to punching IBM punch cards. When the student is ready to enter his program, he reads it in on the terminal's paper-tape reader at 10 characters-per-second. In reducing the length of time to enter a computer program, the connect-time charges for a given program is reduced and the number of student-problems processed increases somewhat. Once a computer education program is underway, even for a short time, the demand for access to the computing resource will outstrip the capacity of a single terminal operated for 3 or 4 hours a day. However, operating several terminals with time-sharing services, quickly becomes prohibitively expensive. There is also the economic disadvantage that the school does not gain equity for the monies it expends. The other disadvantages are that the students cannot obtain "hands on" (i.e. hands on the computer) experience and that most time-sharing services do not have assembly or machine languages available from a terminal.

## III. Small Scale Time-sharing

Most commercial time-sharing services are based on large scale computer complexes costing millions of dollars. However, recent technological advances have led to the introduction of small scale time-sharing systems costing in the neighborhood of one hundred thousand dollars. Typical of these systems are Honeywell's HTSS-16, Hewlett Packard's 2000A/B and Digital Equipment Corporation's TSS-8. They are capable of supporting 16 to 32 terminal users simultaneously. Although these systems do require a large capital investment, they can reduce the time-sharing costs over those using commercial sources. This may seem an attractive approach, especially where several schools and/or school districts can pool their financial resources to acquire such a system. The major advantage over a commercial time-sharing source is that costs are fixed without limiting the amount of terminal usage. Under these circumstances students could be encouraged to experiment and explore during periods when the terminals were not under scheduled use.

The disadvantages of a small scale time-sharing system are much the same as with commercial time-sharing services. Students will require a minimum of 20 minutes at a terminal to accomplish a rudimentary amount of work. Students who are assigned problems will have to be scheduled for time. Someone will have to be assigned responsibility for taking care of the system, tracking down and reporting malfunctions to the appropriate maintenance people. Although students very quickly learn to operate the computer system and can operate it during their free time, some full time staff member should thoroughly acquaint himself with the entire system so that transitions from semester to semester and year to year can be made smoothly.

All of the small scale time-sharing systems support the BASIC programming language. BASIC is easily learned by students and will serve as an excellent tool in solving a variety of problems, demonstrations of concepts, and simulation of experiments. However, BASIC because of its simplicity and convenience, does have some limitations. Students, once they have mastered BASIC, will wish to use something more flexible. In addition, if the educational program intends to teach students something of Computer Science, assembly language will be required. Of the small scale time-sharing systems generally available, only Digital Equipment Corporation's TSS-8 has the capability of offering assembly language programming in a time-sharing environment. Even in this case, the student does not gain the stimulation of "hands-on" experience. The student, at a remote teletypewriter cannot observe or manipulate the computer's registers and hence does not not develop a sense of "what the computer is doing." The terminal user is under control of the time-sharing computer, but the "hands-on" computer user is in control of the computer. For many students this is very exciting, stimulating and a very strong point in their motivation.

IV. Minicomputer System

The third alternative for computing resources is to acquire a computer system. Until recently, the computer systems offered to secondary schools, with the exception of the IBM 1620 and IBM 1130, were primarily designed for business data processing rather than the instructional needs of a secondary school. Generally, these computer systems were too large and expensive for a school and usually required trained personnel to operate and program for them. Even when such machines as IBM's 1620, 1130, 1401's were acquired they were not suitable for general use throughout the school. These systems could not provide adequate support for significant numbers of students unless they were expanded at prohibitively high cost.

In early 1965 Digital Equipment Corporation introduced the PDP-8 at a cost of $18,000. In late 1965 Digital Equipment announced the PDP-8/s for $10,000 complete with a teletypewriter. The development of these two machines ushered in the age of the minicomputer. However, it was not until about 1967 that the low cost minicomputer gained acceptance as a general purpose computing tool. The growth of minicomputers has been almost explosive. In 1967 there were less than half dozen manufacturers of computers selling for less than $15,000. Today (1971) there are over 50 manufacturers who have over 65 different computers selling for $15,000 or less.

V. The minicomputer in the Secondary School

Secondary schools which have acquired a minicomputer, through purchase or lease, operate them either as a single-user batch system or as a multi-user system. Both approaches are limited in the number of student problems which can be processed by the computer.

a) Single-user batch

The single-user batch system is often the lowest in cost and is to be found in a large number of secondary school programs. It consists of a minicomputer with 4096 to 8192 words of core storage and a teletypewriter (with an attached paper-tape reader/punch). The cost of typical systems range from $8500 to $12,000. The programming languages which are generally available, for the student's use, are FORTRAN, BASIC, FOCAL*or an assembly language for that machine. The inefficiency of the single-user system arises because of the inherent slowness of the teletypewriter, which is used as the primary communications (input/output) device, as compared to the high speed processing capability of the minicomputer. The teletypewriter can operate at a maximum rate of 10 cps (characters per second) which is many hundreds of times slower than the typical minicomputer. To input the FORTRAN, BASIC or assembler system into the computer may require as much as 10-12 minutes using the teletypewriter's paper-tape reader. This step may be required more than once during a computer session, especially when using the FORTRAN or assembly language system. The student, who may have previously punched his program on paper-tape, on an off-line teletypewriter, must still spend a minimum of 15-20 minutes at the computer

* FOCAL - is a registered Trademark of Digital Equipment Corporation.

in solving his problem. The addition of a high speed paper-tape reader (300 cps) has helped to improve the efficiency of these systems. However, students will then require the availability of off-line teletypewriters to prepare their programs. Paper-tape handling, itself, can become somewhat of a nuisance. A single-user system, as described, can usually process from 25 to 35 student problem-programs per day.

Single-user batch systems can provide in depth computer training and "hands-on" experience for the student. To the student it is both challenging and exciting to see exactly what the computer is doing, to be able to start and stop it, and to examine and/or alter the value of any register or memory location. By being in such intimate contact with the computer, the student develops a level of understanding he could not otherwise attain. In addition, there generally exists a user library of previously written programs which can only be run on a single-user batch system.

b) Multiuser System

A typical multiuser system will consist of a minicomputer with either 8,196 or 12,288 core memory locations, from 2 to 4 teletypewriters and special equipment to connect the several teletypewriters to the computer. Multiuser systems generally cost between $18,000 and $25,000. All of the multiuser systems, currently available, have only single language capability, primarily BASIC. Multiuser systems behave as a very limited time-sharing system. The student user must enter his program at the teletypewriter terminal (from either the keyboard or the attached paper-tape reader) at each session, since there is no provision for the storage programs with in the computer system. This means that a student who begins a program must punch his program onto paper-tape at the end of his session. The next time he is ready to work on that program he must read in the paper-tape. If he has made any program changes or corrections he must again punch a paper-tape copy of his program at his terminal. As with the other terminal oriented approaches, the student will require a minimum of 20 minutes to make meaningful headway in solving his problems. The program space available to each user is also limited by the size of the memory and the number of users which must share it. This is generally not a problem with beginning students, but it can be a restraint when students attempt advanced problems. Programs with up to 50 statements should present no difficulty. Another point which will affect terminal availability is how the multiuser programming system is loaded. From time-to-time the multiuser system will "crash" or fail; this will vary from once every two days to several times a day, depending on a variety of circumstances. To reload the multiuser program system from a teletypewriter's paper-tape reader (cps 10) requires from 15 to 20 minutes. During this time all the terminals are unavailable. A high speed paper tape reader (about $3,000) will reduce reloading time to about one minute.

A multiuser system can accommodate more students than a single user batch system and provides greater economies than commercial time-sharing or a small scale time-sharing system. The level of computer expertise, on the part of the school staff, required to support and maintain a multiuser system is much less than for a small scale time-sharing system. A multiuser system can also operate as a single-user batch system to provide advanced students with assembly language and "hands-on" experience.

The multiuser system can provide a reasonable compromise between time-sharing's ability to handle several students with a single language and a single-user batch system's greater versatility but limited student handling capacity.

Objective

The purpose of this investigation is to develop a set of general specifications or descriptions for low-cost computing systems which will have greater processing capacity than the computing resources presently employed. The increased processing capacity will permit more students to have access to the computing facility. In developing configurations for low-cost computer systems, a strong effort has been made to make the computer system as modular as possible. This was done so that a school could start with a modest investment and then expand as their experience and needs grew. Each step in the modular expansion would provide an increase in the number of student programs processed by the computer system. Another objective was to keep the cost of the expanded system to about $25,000 while still providing a highly effective computer system. The goal is to be achieved by integrating suitable low-cost peripheral equipment, which has recently become available with a suitable minicomputer. In selecting equipment it is recognized that secondary schools, generally, have no engineering expertise and very little, if any, professional programming experience. Thus any equipment considered, must be easily integrated with a previously chosen computer. Every effort was made to choose equipment with the greatest reliability commesurate with cost and performance. In most schools, a single computer system will have to satisfy a variety of educational roles. Hence, the computer systems were developed to satisfy as many educational functions as possible with an overall consideration to processing as many student programs as possible.

Although the major goal is to design low cost computing system configurations with the capability to process large numbers of student programs, they will also permit the support of some administrative work. Only simple administrative tasks, as attendance statistics should be attempted. Large data processing tasks are likely to tie up the minicomputer and thus defeat the entire purpose - that of having a computer system which has a high availability for student use. The specifications and configurations developed in this study are intended to serve only as a guide for those planning to introduce computers into their schools. For those schools which already have an educational computer system, this study can also be used in planning for future expansions. Although manufacturers are named and approximate prices are given, it is not the intention of this report to endorse or recommend any specific manufacturer or specific equipment. It should be borne in mind that computer technology is a rapidly developing and highly competitive field. The price and equipment availability picture is likely to change in six months or a year. The general trend, however, is for prices to drop and for a greater variety of equipment to become available. Computers and/or equipment which were not considered suitable e.g. because they lacked adequate software such as a BASIC or a FORTRAN system at the present time (December 1970), could become a suitable choice in the future.

Method and Approach
I. Background to Survey

The minicomputer has experienced an almost explosive growth in the last half of a decade. When the Digital Equipment Corporation (DEC) introduced the PDP-8 at $18,000 in 1965 and the PDP-8/s at $10,000 in 1966, they were virtually alone as manufacturers of low cost minicomputers. Within the next two years, DEC was joined by several other manufacturers of minicomputers. During this period, the principal use of minicomputers was to be found in industrial, engineering and scientific applications. In these areas the minicomputer functioned as a special purpose digital computer or controller rather than a general purpose computational tool. Even today, the vast majority of computers are to be found in industrial environments and in special purpose applications. It was not until about 1967-1968 that the minicomputer gained general acceptance as a computational tool. This was largely brought about by the availability of high level programming languages such as FORTRAN for minicomputers. Although minicomputers could not compete with larger computers in large scale scientific calculations, they could do small laboratory and engineering design calculations. Quite often they became a researcher's "private" computer.

As the acceptance of minicomputers grew, so did the number of manufacturers. By 1969-1970 there were over fifty manufacturers in the United States who offer some 65-plus different models of computers selling for under $14,000 with many selling for less than $10,000. Technically speaking, they are all general purpose computers, however, some have been designed to be marketed in special application areas such as in communications or industrial process control. This is often a factor in determining a manufacturer's attitude toward providing service, maintenance, and software support. These are the basic services which are the very minimum that any high school would require.

Prior to 1966 only a few secondary schools could afford a computer of their own and then they were usually private schools. In 1967-1968 several large projects were undertaken to introduce computer concepts into the secondary educational program. Project LOCAL in Massachusetts, the Huntington Project in New York and the Computer Instruction Network in Oregon are but a few of the many programs initiated throughout the nation. Most of these programs utilized a commercial time-sharing service or purchased one of the PDP-8 family of computers (PDP-8, PDP-8/s, PDP-8/i, PDP-8/l). At that time choosing a minicomputer was a relatively simple task. A member of the PDP-8 family was the only logical choice at the time. Nowadays the choce is somewhat more complex in that there are so many more minicomputers to choose from. Some will make excellent educational computing systems while others could prove to be a waste of money.

Another area which has important implications for low cost educational computing systems is the availability of peripheral equipment. Peripheral equipment consists of such devices as punched-card cardreaders, printers, auxiliary storage disks, magnetic tape drives and cassette tape storage systems. Peripheral equipment is used to communicate, both input and output, with the computer. It is this kind of utilization of peripheral equipment which permits the computer to process large numbers of programs and great volumes of data. Without the proper peripheral equipment it would be impossible to realize the full potential and capabilities of the modern digital computer. Traditionally peripheral equipment has almost always cost more than a minicomputer itself. Because of the prohibitively high cost of peripheral equipment, secondary schools were limited to using the teletypewriter or at best a high speed paper-tape reader/punch as the input/output device for their minicomputer.

Until recently (late 1969) there has been little in the way of low cost peripheral equipment for the minicomputer. However, in these last few years there has been a rapid growth in the availability and variety of peripheral equipment for the minicomputer. This growth has been in part due to technological developments and in part to the widespread acceptance of the minicomputer. The availability of low cost peripheral equipment permits greater effective use of the inherent processing capabilities of the minicomputer. The educational computer system in the secondary school, utilizing low cost peripheral equipment, will be able to process many more student problem-programs than it could using the teletypewriter alone.

An extensive survey and investigation of the minicomputer and peripheral equipment market was undertaken to determine what suitable equipment is currently available. The survey was conducted in two major parts. The first part consisted of determining which of the minicomputers has suitable characteristics for a low cost educational computing system. How this determination was made will be discussed shortly. The second part was essentially a search for suitable low cost peripheral equipment which could be easily integrated with a minicomputer to attain the desired goals. Peripheral equipment forms the input-output interface between the students and the computer. Hence, it was quite natural to examine the media used in input-output together with the devices with the view of improving the student-computer interface. This phase of the survey will be discussed later.

## II. Survey Criteria

To determine what minicomputers were currently available some forty-six (46) minicomputer manufacturers were contacted and information concerning their computers was requested.

The information requested covered the following three categories:

I. Hardware -

1. Programmers reference manual, computer specifications and I/O interface specifications.

2. Peripheral equipment available from manufacturer and the OEM vendor.

3. Price list.

II. Software -

1. Reference manuals for manufacturer supplied assemblers, high-level languages (BASIC, FORTRAN, ALGOL), editors and utility packages.

2. Availability of basic support routines and application programs.

3. Peripheral equipment software support.

III. Miscellaneous -

1. Availability of field service and maintenance.

2. Existence of a users group and/or educational users group.

Appendix A lists most of the minicomputers reviewed together with the manufacturer's name and address. Several manufacturers and/or their minicomputers are not listed for one of a number of reasons. These include withdrawal from the market, inadequate documentation, and computers designed for special or limited purpose applications. Minicomputer manufacturers vary widely on how they arrive at the prices they quote. Some basis was necessary even for a crude comparison of relative costs. The basis chosen is a "minimum usable configuration," consisting of the manufacturers standard general-purpose central processing unit, 4096 words of core memory and a teletypewriter, model ASR-33, interfaced to the CPU. The minimum configuration will permit the use of the manufacturer's assembler, editor and several other small utility programs in nearly every case. With few exceptions, most high level languages required at least 8192 storage locations and some required 12K storage.

The hardware, software and miscellaneous information, as supplied by the manufacturers, was evaluated against four major areas of characteristics. These four areas served to eliminate those machines which would make them unsuitable in an educational environment. The four areas of characteristics considered are:

1. Design architecture and operation characteristics.
2. High-level language availability.
3. Peripherals available, modularity and ease of expansion.
4. Price and service availability.

From the computer descriptions and programmer reference manuals, it became evident that some computers were designed for purposes other than as a general purpose computer. Computers such as Motorola's MDP-1000 or Texas Instrument's TI-960 were primarily designed for the communications market. Those computers which were primarily designed for special markets were eliminated from further consideration, unless they had some other outstanding characteristics. Computers, such as

Compiler System's CSI-16 and Viatron's 2140 and 2150, were eliminated since they are not really in production. Furthermore, secondary schools should stay away from computers which are new or which have only a relatively small number (25-50) of installations. It may be very exciting to have a newly designed machine, but it is more likely that you will have problems. Discovering engineering and design faults as well as suffering with software inadequacies is no joy and it will severely hamper any educational program.

The availability of service and maintenance was considered to be very important for the secondary school computer systems. Even the most reliable of computers will fail from time-to-time. Peripheral equipment is even more prone to failure than the computer itself. It is neither likely nor wise for the secondary school to undertake the sole responsibility for the maintenance of the computer system by themselves. Therefore we further eliminated those manufacturers that did not have adequate maintenance and service facilities. Companies such as Datamate Computer Systems, Spiras Systems, Foto-Mem, Inc did not have the adequate service facilities that would be required to support an educational computing facility. Some manufacturers have arrangements with national service organizations, such as RCA, General Electric or other independent service companies to provide service and maintenance on a contract basis. It is generally better to obtain maintenance from the manufacturer himself whenever possible. However, for some remote communities, obtaining maintenance through a national service organization may have to do. In this case it is best to choose a computer with which the service organization already has local experience. Before selecting a computer, it is most important to be certain of adequate service and of the costs involved.

Next, computers were compared against their minimum system costs. It was found that most computers costing $12,000 or less were more than adequate. Those computers which cost more than $12,000 did not offer significant advantages. A case in point is Hewlett-Packard's 2116C and the 2114C at $22,000 and $10,500 (minimum systems cost) respectively. The HP2116C is only slightly faster and permits a greater number of options than does the HP2114C. For the most part those options would not be used in an educational environment. Since both computers are otherwise identical, and will run the same programs, there does not seem to be any significant advantage in the HP2116C over the HP2114C. Thus computers with a minimum system cost of over $12,000 were also eliminated from further consideration.

Another major criterion was the availability of a high level language such as BASIC, FORTRAN, or ALGOL. From the software information supplied by the manufacturers we eliminated those computers which did not have at least one high level language. BASIC was considered the preferred language since it has gained widespread acceptance, especially at the secondary school level. Although more minicomputers had a FORTRAN compiler than had BASIC, FORTRAN was considered somewhat less desirable. This is because a great deal of curriculum materials has been developed around BASIC. It would be difficult to use such materials as the CAMP* series with a FORTRAN compiler. There is also a very important operational advantage to BASIC over FORTRAN. The BASIC system is an interpreter, hence it remains intact during the execution of a program and does not have to be reloaded for each program. On the other hand, FORTRAN is a compiler and requires reloading after a program has been executed. Reloading the FORTRAN system can be a time consuming process unless a high speed peripheral device is available. The only computer with an interpretive version of the FORTRAN system is Interdata's I4 which is designed to be used in a multiuser system. However, whether one needs BASIC or FORTRAN or both should really depend upon the nature of the educational program. It should also be mentioned that some secondary schools which have a PDP-8 family computer find FOCAL preferable to either BASIC or FORTRAN.

None of the manufacturers has a high level language specifically for business data processing. However, BASIC is quite acceptable for many businesses and commercial types of problems. Varian Data Machines claims to have a RPG-IV (Report Generator) but no information or manuals were available at the time this report was written. RPG is used in business and commercial problems.

The input-output structure of the remaining minicomputers was reviewed and found to be quite similar. Digital Equipment Corporation has adopted a unified bus architecture for their PDP-8/e and PDP-11 minicomputers. This design approach should make for cheaper interfaces and control logic for peripheral devices. Hewlett-Packard has also made it relatively convenient to interface to their computer (HP-2114C) by providing a number of I/O slots. Although the different minicomputers varied in the nature of their interrupt structure, they were all sufficient to handle the input-output requirements of any educational computing system.

The peripheral equipment offered by the various manufacturers were of the same basic types. The peripherals generally listed include

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*CAMP - Computer Assisted Mathematics Program. A series of secondary school mathematics enrichment texts utilizing the BASIC programming language. The series is published by Scott, Foresman and Company.

additional memory units, high speed paper-tape reader and punch, magnetic tape units, magnetic disk storage units, punch card readers, teletypewriters, line printers and data communication controllers (for data-sets). In addition, all of the manufacturers offered a variety of equipment intended for industrial and scientific applications which have little application in an educational computing system. Not surprisingly, the prices did not differ greatly for similar types of equipment. The greatest price variations, besides the computer itself, were in the computer related options. Hardware multiply and divide instructions are not usually included in the standard minicomputer (except for the Westinghouse 2500). The addition of the hardware multiply/divide feature ranged from a low $350 in the Interdata I4 to $2500 for Lockheed's MAC-16jr and Unicomp's COMP-16. In the Hewlett-Packard's 2114C a multiply/divide feature does not appear to be available. When hardware multiply/divide is not available, multiplication and division is done through software, i.e. program subroutines. Although software multiply/divide takes more time than hardware multiply/divide, this does not appear to be much of a problem for student type programs. In fact, most manufacturer's FORTRAN and BASIC systems assume that hardware multiply/divide does not exist. Another area in which there was a surprising variation in prices was in additional memory units. Hewlett Packard's price for an additional 4096 words of 16 bits each was $4500. This seems disproportionately high to the rest of the manufacturers, especially considering that it is a relatively slow 1.6 microseconds ($10^{-6}$ seconds).

## III. Observations on the Selected Minicomputers

The minicomputers which were judged by the above criteria to be suitable for use in a secondary school educational computing system are indicated by an asterisk following the model designation in Appendix A. Some general observation of these computers are in order at this point.

1. Word size: All of the recommended minicomputers have a word size of 16 bits with the exception of the PDP-8/e, which has a word size of 12 bits. The smaller word size is of little importance in an educational computer. This is especially true when a high level language, such as FORTRAN, BASIC or FOCAL is used.

2. Number of instructions: The number of instructions which a given computer has is also not very important in an educational computer. Overall they have about the same basic computer instructions. Some computers are more efficient for certain kinds of problems than others, but this doesn't really matter for most student problems.

3. Cycle time: The basic speed of the computer is a yardstick often used by computer salesmen in comparing computers. Speed may be of primary concern in an industrial application, but in the secondary school environment it is of less concern. A well written BASIC system on a slow computer will perform better than a poorly written BASIC on a faster computer.

4. Educational institution support: Only Digital Equipment Corporation and Hewlett Packard have made formal corporate commitments to the secondary school educational market. Data General also appears to have some orientation toward the educational market.

5. Third generation: computer salesmen use the term "third generation" to mean several things. All of the recommended minicomputers are of third generation technology, integrated circuits. "Third generation" is also used to allude to IBM-like design. However, of all the minicomputers, only the Interdata I4 resembles the IBM 360 series in design philosophy.

6. Equipment costs: All peripheral equipment devices will require controllers, a separate electrical power supply, connecting cables and cabinetry. Be sure to obtain complete costs when planning a computer system.

7. Software support for peripherals: All the manufacturers supply basic software support for the peripherals they sell. However, one should be certain that there is sufficient support for the intended use of the peripheral device. For example, a junior college was sold a minicomputer and a magnetic disk storage unit. There was insufficient software for the school to utilize the disk in its computer education program.

8. Semiconductor memories: Semicondoctor memories are a new development and are meant as a replacement of core memories. Besides their being more expensive, semiconductor memories have another characteristic which makes them less than desirable in an educational environment. When the computer is shut off, all of the programs (i.e. bootstrap loader, loaders or the BASIC interpreter) stored in a semiconductor memory are lost. Core memories generally retain information stored in them even when the computer is shut down.

## IV. Peripheral Equipment, General

Investigating the low cost peripheral market was somewhat more difficult than the minicomputer market. Peripheral equipment manufacturers are oriented toward and prefer to deal with the computer manufacturers, manufacturer representatives and engineering firms specializing in custom designed computer systems (sometimes referred to as system houses). Peripheral equipment manufacturers generally do not provide an interface to a minicomputer. Most peripheral manufacturers will rely on computer manufacturers or system houses to design and manufacture controllers for their peripheral devices. Even when controllers and interfaces are available for a given minicomputer, the only software to support the peripheral device may be diagnostic programs. A peripheral device will require a different interface and software package for each minicomputer. Therefore, peripheral equipment manufacturers usually leave the design and manufacture of interfaces and software programs to the computer manufacturers and to system houses.

The peripheral equipment survey was in two broad categories. The first category included those devices which are directly involved in student interaction. This category includes paper tape handling devices, printers and card readers. The second category includes bulk storage devices such as magnetic disk, drum, and tape storage devices. The computer manufacturers as a whole, offered nearly the same types of equipment at roughly the same prices for equivalent equipment. Since the computer manufacturers rely on peripheral equipment manufacturers for the devices they offer, it was not surprising that a number of computer manufacturers offered the same devices, e.g. printers manufactured by Data Products, Inc. Only three computer manufacturers offer peripherals of their own design and manufacture. Digital Equipment Corporation (DEC) offers DECtapes, DECdisk and DECwriter for their PDP-8 series and PDP-11/20 computers. DECtape is a proprietary magnetic tape system utilizing 4 inch diameter reels of 3/4 inch wide magnetic tape. DECtape has been available for DEC computers for about 5 years and appears to be highly reliable and relatively low in cost when compared to other magnetic tape systems. DECdisk is a small system comparable with other disk systems. The DECwriter is a teletypewriter-like device which prints at 30 characters per second. It appears to be an attractive alternative to Teletype Corporation's KSR-35, a heavy duty teletypewriter (see glossary), at least for the DEC PDP computer systems. Hewlett-Packard also manufactures and markets sense card readers which are interfaced to the HP2114C computer. Interdata has designed and manufactures a magnetic tape cassette system, called INTERTAPE, which is interfaced to their I4 minicomputer.

In considering any piece of peripheral equipment for inclusion in an educational computer system several points must be taken into account. We must be concerned with how it will be used in the educational computing environment, that is, what purpose will it serve.

We must also consider what additional hardware is necessary, whether the manufacturer can supply adequate software and who will provide maintenance. An actual case history will serve to indicate why these questions are important.

An educational institution was given a grant to purchase a minicomputer system. They choose one of the minicomputers, included in our recommended list, with 12K words of core memory and communications hardware to support a four terminal multiuser BASIC system. In addition, they purchased a 262K word disk storage system from the computer manufacturer. The thought was to run the manufacturers disk-operating system (a supervisory program) to reload the multiuser system from the disk when required, to keep program files from the multiuser BASIC system and to run the manufacturer's FORTRAN compiler. After the allocated funds were spent and the system was delivered it was found that the disk could not be used after all. The multiuser BASIC system did not support program files on disk. There was no software available to load the multiuser system from disk and the manufacturer's disk operating system required 16K words of core memory to be used at all. The net result is that the disk storage device is unused at present.

When planning for peripheral equipment it is important to bear in mind why and how the peripheral equipment is to be used in the educational computer environment. Despite the best representations of the computer manufacturer's salesmen, it is best to be skeptical and take a 'show me first' attitude. The purchase contract should briefly indicate how the peripheral is to be used and what software support is expected of the manufacturer. This approach should also be used when purchasing from a peripheral manufacturer.

Consideration can now be given to which peripherals and under what circumstances they should be purchased from the computer manufacturer or from an independent equipment manufacturer. In general it is advisable to obtain peripheral equipment from the computer manufacturer except when there is a substantial price differential or when the computer manufacturer does not offer type of peripheral. The reason for this advice is as follows:

1) The computer manufacturer has equipment made to his specifications and he is responsible for it's quality.

2) The computer manufacturer has to make the peripheral work with his computer. Manufacturers often make subtle modifications to the original peripheral.

3) The computer manufacturer is in the best position to supply adequate software for utilization of the peripheral equipment. The manufacturer can also be pressed for any additional software support for the peripheral device.

4) The comnuter manufacturer is obligated to provide maintenance service for all his equipment. He cannot shift the blame to someone else when some equipment fails to function as specified.

5) Members of the computer user's group are likely to contribute programs and routines for the manufacturer's line of peripherals.

## V. Disks

All the computer manufacturers of the recommended computers have a broad line of disk storage devices to choose from. Although there are a number of independent equipment manufacturers who offer very attractive disk-systems, this author believes that it is still best to obtain the systems through the computer manufacturer. This is especially true for the secondary school with it's limited engineering and programming experience. Disks are among the more difficult devices to program for. Therefore, the educational institution should depend upon the programming resources of the manufacturer to provide the disk software. Once again we stress the need for planners of an educational computing system to be certain that the computer manufacturer has adequate software to utilize the disk storage device in the intended manner, and that the planned computer configuration will support both the disk and it's software.

Disk storage systems, generally are either fixed head with a non-removable storage media or a moving head with removable storage media (referred to as disk pack or disk cartridge). The latter provides for a more flexible and expandable storage system. Moving head disk devices, however, may require greater maintenance service than fixed head devices, since they incorporate electro-mechanical head positioners. Advancing technology has made them considerably more reliable than they have been in the past. The most common disk cartridge in use with minicomputers is the IBM 2315 disk cartridge. Although IBM 2315 disk cartridges may be physically interchanged between disk drives of different manufacturers, the recorded information generally is not.

This author has chosen not to list any of the independent disk manufacturers or systems houses offering disk systems because of their uncertain software support and maintenance. One last point should be made with regard to systems houses. While they may supply disks, controllers, and interfaces and may claim "plug-to-plug compatibility", it is possible that their disks may not be software compatible with the computer manufacturers software or disk operating system. In some cases, a computer manufacturer can be persuaded to provide a disk system not normally in his equipment list.

## VI. Magnetic Tapes

The IBM compatible magnetic tape storage devices do not appear to be especially attractive for a low cost educational computer system. The major use of IBM compatible magnetic tape in an educational computer system has been to transfer data from the smaller computer to a larger data processing facility. This has been primarily in the area of administrative data processing. Another use for magnetic tape storage devices has been to reload programming systems from magnetic tape rather than from paper tape. However, this latter use can be accomplished by cassette and cartridge magnetic tape systems at lower cost and with greater convenience. Cassette and cartridge magnetic tape systems will be discussed shortly. IBM-compatible magnetic tape device should also be purchased from the computer-manufacturer for very much the same reasons already stated for disk storage devices.

## VII. Cassette Tape Systems

Cassette and cartridge magnetic tape storage systems provide many interesting possibilities for the low cost educational computer system. For purposes of this report I will also include Digital Equipment Corporation's DECtape system with the cassette and cartridge systems. Appendix C lists those manufacturers of cassette or cartridge storage devices who provide both computer interfaces and supporting software. Although interfaces exist for other computers, interfaces generally do not have supporting software and hence are not noted in Appendix C. DICOM, SYKES and Tri-Data provide maintenance and service directly or through a sales/service representative. Digital Equipment will also provide maintenance for the Tennecomp TP-1351. Tri-data and Tennecomp use proprietary cartridge designs. Additional cartridges of tape are available only from the manufacturers. Dicom, Interdata and Sykes use a standard Philips type cassette but of computer quality. These cassettes are available from the device manufacturers or from a number of independent sources.

Magnetic tape cassette/cartridge systems can be used as a high speed substitute for paper-tape or as a low cost replacement for the standard magnetic tape transport. In the simplest applications, the cassette storage system would be used to load in the BASIC or FORTRAN system. This can represent a significant savings in time, over the use of a paper-tape reader. For example, to load the BASIC interpreter from a teletype paper-tape reader would require about 13 minutes. Using a high speed paper-tape reader would require about a half minute. A cassette storage device would require about 15 seconds. The cassette would reduce the amount of paper-tape handling. The cassette could also be used to store BASIC programs for later use. Here again, the computer system planner must make sure that the cassette manufacturer has adequate software to support this kind of use on the selected computer. A more sophisticated application would employ multiple cassette transports. One cassette would contain all the system software including, say, a FORTRAN compiler. The user would load in the FORTRAN compiler from the systems cassette, read in his FORTRAN program from the teletypewriter, and compile his program onto another cassette in binary form.

The binary program would then be loaded into the computer and executed. The multiple cassette transports could be used in applications requiring updating sort/merging of data files. This could all be done more or less semi-automatically assuming an operating system existed for the computer-cassette combination. Such an operating system does indeed exist for Interdata I4-Intertape, and for the Dicom - Hewlett Packard 2114, Data General NOVA 1200/800, DEC PDP-8 series and for DECtape - PDP-8 under the PS/8 DECtape monitor system. The cassette/cartridge magnetic tape storage devices integrated with a minicomputer can provide a low-cost computing system for the educational environment. Some useful configurations will be indicated together with approximate costs.

## VIII. Input devices - Mark Sense Readers

The next areas of concern are the devices and media used by the students to communicate with the computer. For minicomputers this has traditionally been the teletypewriter and paper-tape. This is the usual situation whether the minicomputer is operated as a single-user, multiuser, or time-sharing system. The teletypewriter, still remains the lowest cost input-output device for the minicomputer although it is not the most efficient. The teletypewriter, because of its slow 10 characters per second speed, is inefficient in terms of the computer's speed and also in terms of student's utilization. The limitations imposed by the use of a teletypewriter on computer resources was discussed earlier in this report (see part A, sections II- V). High speed paper-tape readers (200-300 characters per second) and offline teletypewriters do help to increase the number of student problems processed by the minicomputer system. These high speed paper-tape readers are available from the computer manufacturer at a reasonable price. However, offline preparation of programs still leaves much to be desired. Typing errors are difficult to correct. These errors must be corrected by copying and repunching, by "scissors and paste," offline, or by use of an interactive editor at the computer, online. This is in contrast to the ease in using the punched card in programming for the larger machines. It is relatively easy to repunch and correct a card. However, the use of punched cards, generally, entails the use of an expensive card reader and the rental or purchase of key-punching equipment. Recent advances in technology has led to lower cost card readers suitable for use with minicomputers. These card readers are designed to read cards (and input them to the computer) at the rate of 150-200 cards per minute. Key-punching equipment has three drawbacks. They are a recurring expense; they require maintenance; and most importantly, students must have physical access to them in order to punch their programs. The development of the mark sense card reader obviates all three disadvantages in the use of a card reader with a minicomputer system. The mark sense card reader has a number of distinct advantages over other forms of input to the computer, in an educational environment. The mark sense card reader permits input speeds compatible with the processing speed of modern minicomputers. The student can do his "programming" almost anywhere by marking his cards with a soft lead pencil. The student can edit and correct his program using an eraser and pencil. Corrections can be made as easily as erasing the unwanted marks and adding new ones. Mark sense cards are designed so that the student can easily mark the proper codes for letters, numerals and special symbols. Unlike paper tape, the student can easily read the mark sense card and visually verify what he has recorded on the cards. Mark sense cards can also be punched, if some keypunch training is desired, and read by the mark sense cardreader provided certain restrictions are met. Mark sense cards can be designed for efficient use with a particular programming language such as BASIC or FORTRAN.

Appendix D illustrates some typical examples of unmarked and marked cards. Several other standard card forms exist and are available from the computer and/or card reader manufacturer. The Motorola MDR mark sense reader can also read page size forms with the mark sense information along the side edge. This can be extremely useful in test and questionnaire processing since the answer form can be a part of the test or questionnaire.

In addition to the above uses, mark sense cards can also be designed for testing and questionnaire scoring. Attendance reporting, grading, class ranking, registration and other administrative functions can be automated. In this connection, it should be pointed out that mark sense cards can be partially punched and partially marked. The classroom teacher can be given a set of cards with the student names prepunched on the cards. The teacher would then mark sense the required information such as attendance or grades. Programs, of course, would have to be written to process the cards.

Appendix E lists the four most widely used low-cost mark sense card readers. Digital Equipment Corporation is also listed, although they do not manufacture the mark sense card reader offered. They in fact use the card reader manufactured by GDI. If a computer manufacturer does not offer a mark sense card reader, he can usually be convinced to provide one of the first three card readers listed, together with a suitable interface. The interface should cost between $800 and $1500. The mark sense reader and interface should be program compatible with the computer manufacturer's punched-card card reader so that existing software can be utilized. The principles by which the mark sense card reader operates, the use of reflective and non-reflective inks, etc., is best left to the manufacturer's literature (see appendix E for names and addresses).

Digital Equipment Corporation and Hewlett Packard have recognized the many virtues of mark sense cards. Both have recently developed educational computer systems around the mark sense card.

## IX. Output Devices - Printers

For minicomputers the standard output device has been the teletypewriter. As an output device, the slow speed of the teletypewriter is a greater limitation on the computer system than as an input device. The amount of information to be output, generally exceeds the input information. The information output of a minicomputer system will depend on it's mode of operation. In the single-user batch mode, the output may consist of binary information, punched on paper-tape, as well as alphanumeric characters to be printed. In the multiuser mode, all information between the users and the computer is information to be printed. In the case of input, high speed paper-tape readers are available at a reasonable cost. Although paper-tape readers can operate reliably at 300 characters per second, the fastest paper-tape punch, generally available, will operate at only 60 characters per second. The speed of paper tape punches is quite adequate for the binary information, but teletypewriter printing speeds limit the processing capacity of a minicomputer system.

High speed paper-tape punches are available from the computer manufacturer and are often combined with a high speed paper-tape reader. The reader-punch combination will often cost less than when purchased as individually units. Since the high speed paper-tape punch is adequate at handling binary output, this survey concentrated on devices for printing information. It is in the area of printing devices, that the greatest variation of technologies and approaches is to be found. The most popular printer among the computer manufacturers appears to be the Data Products printer 2000 series and 4000 series. From the computer manufacturers these printers range in price from $12,500 to 17,500, depending upon speed, number of print columns, and other features.

In surveying the available printing devices four criteria were established:

1) 300 lines per minute was established as the maximum useful speed for printers operating with a minicomputer. The cost of printers is generally proportional to their speed and little benefit will be gained by faster printers.

2) $10,000 was established as the absolute maximum cost for any printing device interfaced to the computer.

3) Reliability - printers are electro-mechanical devices and have been traditionally the least reliable of the peripherals. A strong effort was made to identify those printing devices which have been designed with a strong emphasis on reliability or which utilize inherently reliable technology.

4) Service availability. The manufacturer of the printing device must be able to provide service nationwide.

Printing devices can be grouped by three characteristics. Printers which print a single character at a time or a whole line at a time. The teletypewriter is the most common example of a character at a time device. Printers which print a character at a time are lower in cost as well as low speed, while line printers are higher in cost and operate at higher speeds. A strip printer, prints characters on a strip of paper (3/8 - 1/2 inch wide) and page printer uses paper 8 1/2 inches wide (72 or 80 print columns) or full width computer paper 15 inches wide (120-130 print columns). Strip printers are not suitable for an educational environment.

The third characteristic is the type of printing technology employed. Impact printers strike a print element against a ribbon and the paper. The print elements may be on a rotating wheel, cylinder, drum, chain or on an oscillating bar. Non-impact printers use thermographic (heat sensitive) or electrostatic techniques which generally means specially treated papers. Another non-impact printer technique is the ink jet. In this approach a jet of ink droplets is squirted onto ordinary paper to form the characters. Non-impact printers are generally more reliable than impact printers. Impact printers can produce multiple carbon copies, while non-impact printer can only produce one copy. This does not appear to be a limitation for the general educational environment. The specially treated papers used in non-impact printers are fairly expensive. The ink jet printers are favored by the author because they combine a moderate speed; an inherently reliable technology; use ordinary paper; are relatively quiet; have been interfaced to a large number of minicomputers and are reasonably priced.

A number of the character printers are designed to substitute for the teletypewriter normally used with the minicomputer. All of these devices cost more than the teletypewriter but operate substantially faster and are generally more reliable than the model 33 teletypewriter.

Most of the printing devices listed in Appendix F have been developed over the last two years. Some of the printer manufacturers, such as Nortec and Centronics provide a minimum of interface electronics and rely on large system houses such as Daconics, to interface, sell and service their printers. Most manufacturers can provide the interface to the more popular minicomputers. Almost all of them have an interface to the PDP-8. Appendix F does not attempt to list all the printers available - there are well over 100 different types. Appendix F indicates the printers which the author feels may best suit an educational computing system.

Results and Systêm Configurations

The evaluation guide lines expressed in the preceeding sections together with the appendices should be of assistance to anyone planning to implement an educational computer system. As was pointed out early in this report, the minicomputer industry is characterized by a state of constant change. The change is in the direction of lower prices, improved performance and of greater variety in equipment and software. The equipment selected for the appendices represents what the author feels to be suitable (and presently available) in designing an educational computing system.

The goal stated in the "objectives" section, was to design a computer system with a high processing capacity in order to serve as many students as possible. These computer systems have to be modular, expansible, and low cost. In this section we will put all the pieces together to meet our objectives. All the computer systems to be described can serve a variety of purposes, but a few will have characteristics or software suitable to some very special educational goals. For example, in a vocational program, one of the goals might be to teach assembly and machine language programming skills which can be transferred to the IBM 360/370 series of computers. In this situation an Interdata I4 would be a better choice than any other minicomputer. The I4 is the closest in architecture and structure to the IBM 360/370 computers. In addition, the computer system based on the I4 could meet most of the other educational objectives of the secondary school. For the secondary school desiring to emphasize commercial data processing, the Varian 620/L configured to support RPG IV, might be the best choice. Before we present some possible configurations we can state some specifications and guide lines.

1) The basic computer should cost under $10,000 except when the computer can meet some special educational requirement.

2) The computer must have at least one higher level language, preferably BASIC, in addition to assembly language.

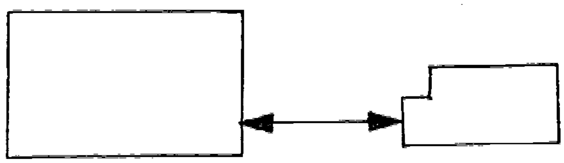
3) The computer manufacturer should be able to provide adequate maintenance from a nearby service center.

4) The computer manufacturer should provide adequate software support in order to utilize his equipment.

5) The computer should support a multiuser system as well as a single-user system.

We can now present some configurations and show how they can be expanded to process larger numbers of student programs. For purposes of illustrating the configurations and approximate pricing we will specify a particular machine. It should be understood that a number of the minicomputers and equipment listed in the appendices could be substituted as well.

Single-user system also supporting the BASIC language



| | |
|---|---|
| PDP-8/e | |
| with 4K memory | $4990 |
| Teletypewriter | |
| ASR Model 33 | 1500 |
| Total | $6490 |

Computer
with 4096 words
of Core memory

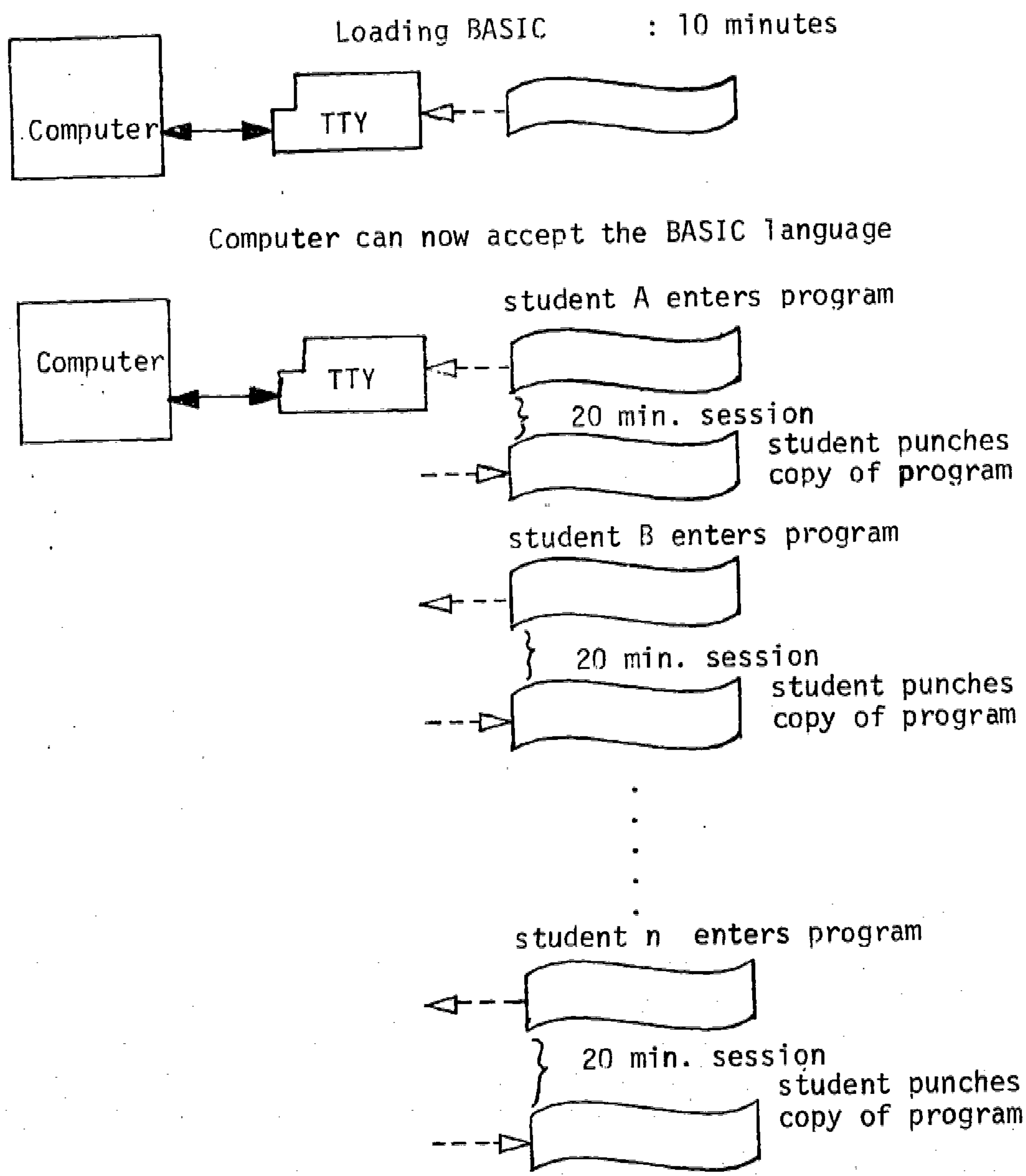
Teletype
ASR Model 33

Figure 1

The computer system illustrated in Figure 1 is the least expensive system to acquire. It is the most common configuration to be found in the secondary school environment. In some instances the configuration may include an 8K memory to permit the use of a FORTRAN compiler. These computer systems can support 40 to 60 students, per semester, using an interpretive programming language such as BASIC. If assembly language or FORTRAN compilers are also used, then 20 to 40 students can be accommodated. This difference is due to the nature of interpreters and compilers. Interpreters such as BASIC remain in the computer from student to student. The time required to load BASIC (about 13 minutes) is relatively insignificant since it may be done once or twice a day. On the other hand, assemblers and compilers are reloaded from student to student. The loading time (about 10 minutes) is now a significant portion of time, and thus fewer students can be accommodated. Figures 1a and 1b illustrates how the computer is utilized with an interpreter and with a compiler. The addition of an offline teletypewriter would permit one student to punch his program onto paper-tape while another student occupied the teletypewriter attached to the computer. The student would then read in his paper-tape at teletypewriter speed during his computer session. The addition of the offline teletypewriter would thus permit more students to be accommodated. A high speed paper-tape reader or a tape cassette storage system is almost a necessity when using a FORTRAN compiler or assemblers. Without a high speed paper-tape reader or a tape cassette storage system, it would be difficult to run more than a half dozen programs a day. A tape cassette storage device with a monitor can support 40 to 50 students. Figure 1c illustrates a basic computer system augumented with a tape cassette storage system and monitor. The operating characteristics of this system is similar to the operating behavior of a disk based operating system.

As students gain programming experience and sophistication, they will attempt more difficult problems, which will place increasing demands for computer time. Additional students may be entering the computer education program which will make additional demands on the computer

Computer operation using the BASIC interpreter




Note:
A student may require several sessions to complete a problem. Between sessions the student may analyze his errors.

Figure 1a

Computer operation using the Fortran compiler

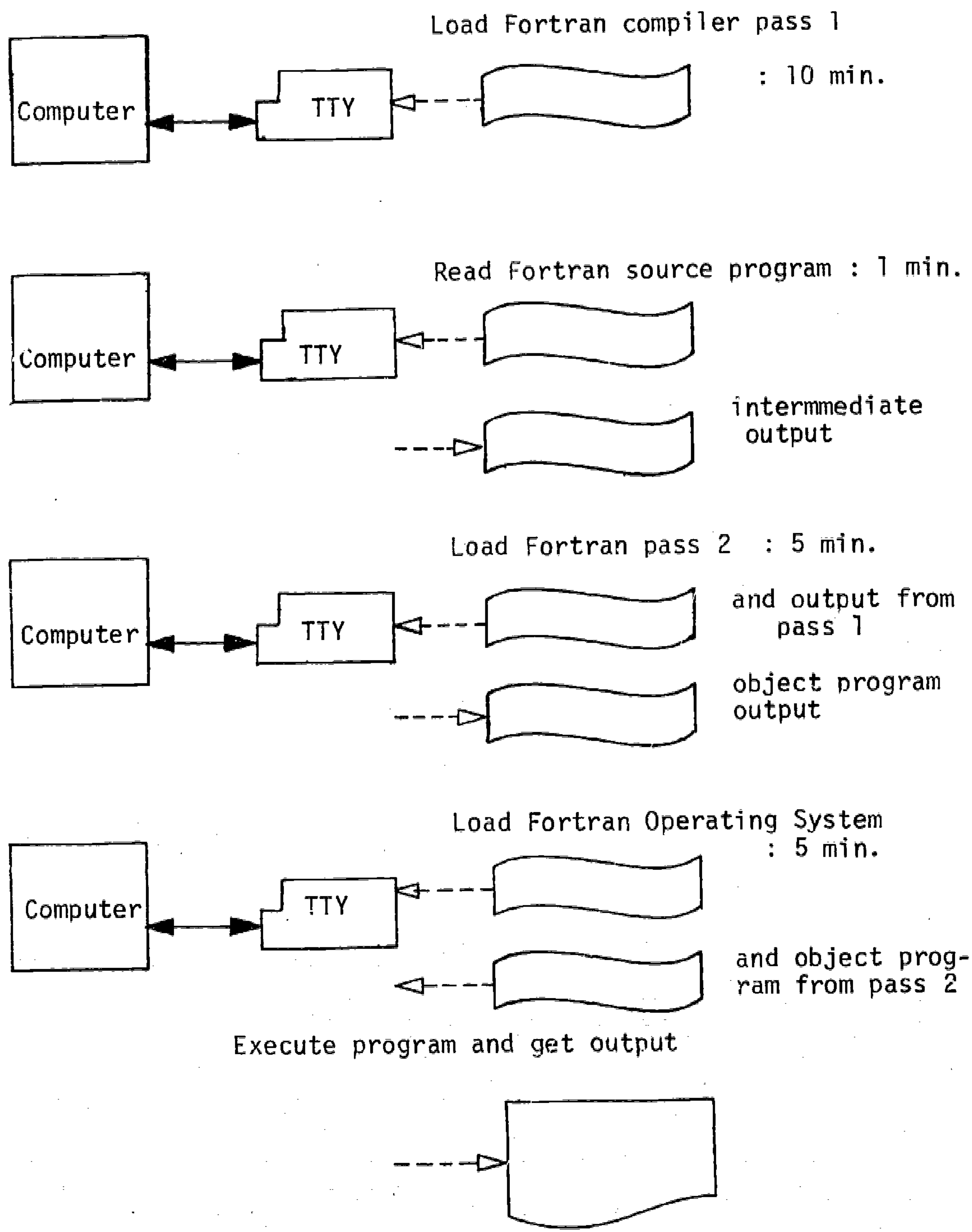



figure 1b

Computer operation with a cassette tape monitor for an assembly

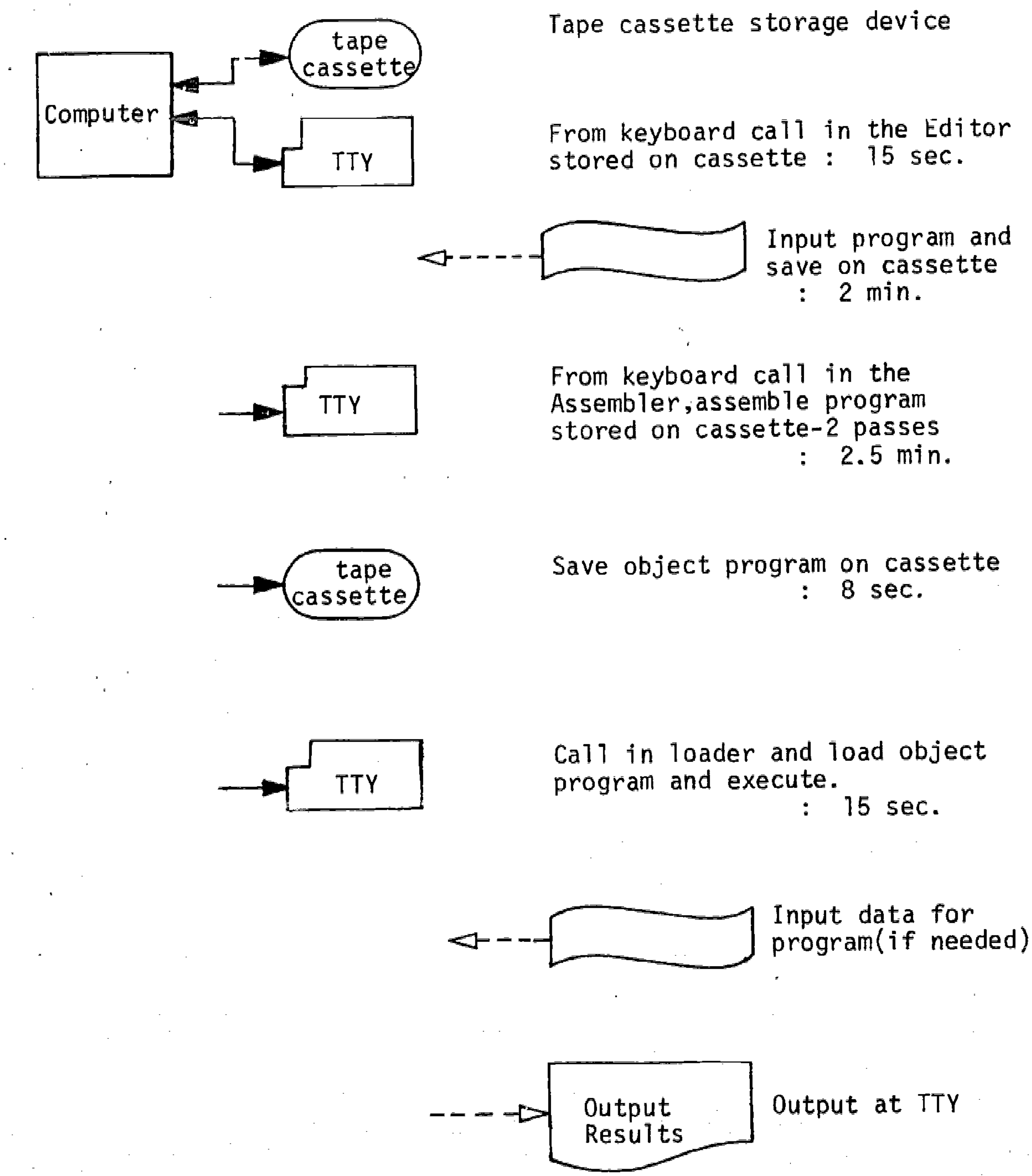
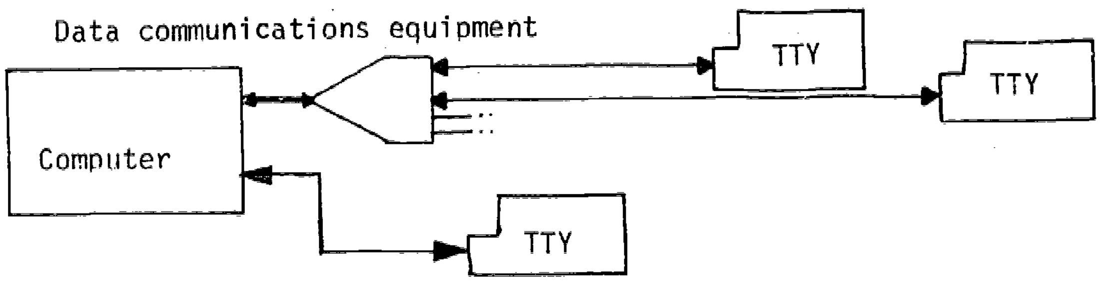



figure 1c

system. If the increased demand can be met using an interpretive language such as BASIC, we can expand the basic configuration along the lines of Figure 2.

A Multi-user computer system




| | |
|---|---|
| 4K PDP-8/e with teletype | 6490 |
| Additional 4K memory | 3000 |
| Data communications for up to 4 TTYs | 1000 |
| 1-3 additional teletypewriters $1500 @ | 1500-4500 |

Totals

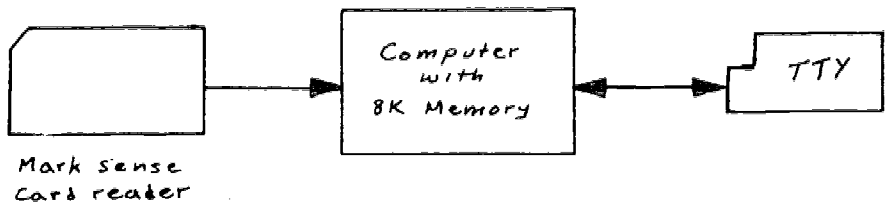
| | |
|---|---|
| with 2 teletypes | 11,900 |
| with 3 teletypes | 13,490 |
| with 4 teletypes | 14,990 |

Figure 2

Once additional memory and data communications hardware has been obtained, up to four teletypes can be added as the need arises. In some multiuser systems there is a limit to the number of teletypewriters which can be added, usually four. Other multiuser systems will accommodate up to 16 terminals provided sufficient memory capacity is added. The multiuser system can also operate as a single user system to provide training in assembly language and FORTRAN. As pointed out in the preceding paragraphs, a high speed paper-tape reader or tape cassette system would greatly facilitate computer use with assembly language or FORTRAN. It would be very useful if the users of a multiuser BASIC system could also save their files on the tape cassette storage system. This would reduce the need for a student to punch his program on paper-tape at the end of his computer session. However, at the present moment, no one seems to have adequate software to perform this task. Each terminal in a multiuser system should support no more than about 50 students at an introductory level where programs will not exceed 25-50 statements.

Another approach which expands on the basic system of figure 1 utilizes a mark sense (optical) card reader. This is shown in figure 3. It has potential for high processing capacity.

Single user computer system and mark sense card reader




| | |
|---|---|
| BASIC 4K PDP-8/e with teletype | $ 6,490 |
| Additional 4K Memory | 3,000 |
| Mark sense card reader | 4,900 |
| TOTAL | 14,390 |

Figure 3

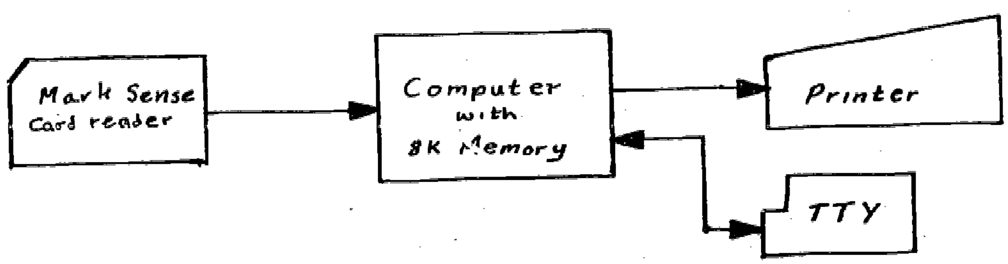
The mark sense card reader is utilized for input and the teletypewriter for printing output. The student, instead of typing or punching his program at the teletypewriter, would mark sense his program onto the mark sense cards. This could be done almost anywhere and at any time prior to approaching the computer. At the computer, the student would drop his cards into the mark sense reader. The computer would read his cards, and a listing of his program together with it's results would be printed at the teletypewriter. The student could take the program listing and output to his desk, locate his errors and make the appropriate corrections to his cards. This approach has a number of operational advantages. First, the student does not require a keypunch nor an off-line or online teletypewriter to prepare his programs. Second, the student does not tie up a teletypewriter while he is thinking and correcting his program. Third, correcting a program can be done with eraser and pencil. Fourth, the problems associated with the handling of paper-tape is virtually eliminated. Fifth, the information on a mark sense card can be read by humans with a minimum of effort, while paper tape is difficult to read and requires knowledge of the paper tape punch code.

In an earlier section (C-VIII) we indicated some educational and administrative uses of mark sense cards. Appendix D illustrates several samples of mark sense cards as used in some application. Either a general purpose or special format card can be used for BASIC, FORTRAN or assembly language. Mark sense card formats can be designed for almost any administrative or testing application. In most cases the mark sense card reader can make use of the same existing software used by the computer manufacturer's punched-card card reader. Digital Equipment Corporation and Hewlett-Packard both have BASIC interpretive systems using mark sense cards. However, any of the other computer manufacturers should be able to provide the necessary software to support a mark sense card reader.

This approach will process programs at relatively high rates of 250 to 400 programs per day. This of course assumes that the programs are simple (20-50 statements) and the output of each program is limited to about a page. To handle larger programs (50 to 250+ statements) will usually require additional memory and/or a disk storage unit with supporting software. However, the primary processing limitation in this approach is the printing speed of the teletypewriter. Programs can be processed much faster than the teletypewriter can print the results. By employing higher speed printing devices the program processing capacity can be increased. The increase in capacity will be proportional to the speed of the printing device. Three hundred to four hundred lines per minute is the probable upper useful limit for educational systems. Faster printers are very costly, generally less reliable, and would not increase system performance significantly. Appendix F lists only those printing devices which operate at speeds faster than the teletypewriter's 10 characters-per-second.

Figure 4 expands on the basic configuration with a mark sense card reader (figure 3) by adding a printing device. The printing device can be a character-at-a-time printer with a keyboard, e.g. DEC's DECwriter, or without a keyboard, e.g. Litton's ABS model 30, printing at about 30 characters per second. Or, a higher speed printing device such as A. B. Dick's Videojet or Potter's LP 3000 printer. Printers with speeds of 100 to 250 lines per minute will provide about the best cost to performance ratio.

Single user computer system, mark sense reader and printing device



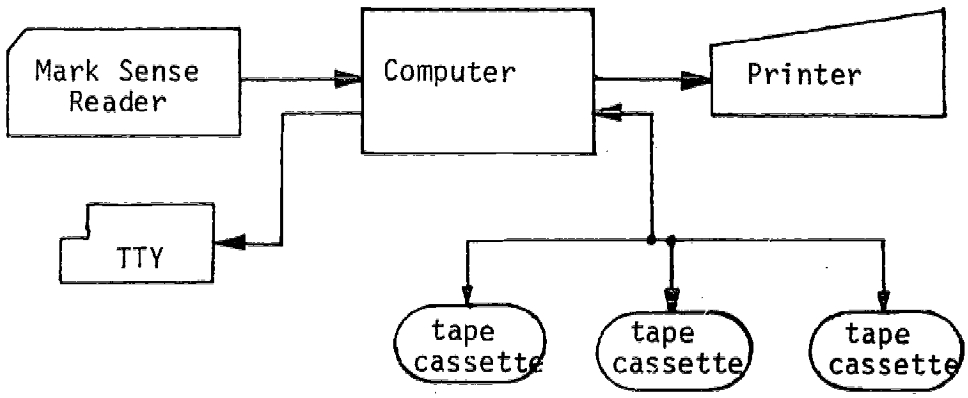

| | | |
|---|---|---|
| Configuration in figure 3 | $ 14,390 | $ 14,390 |
| DECwriter | 2,850 | |
| A.B. Dick Videojet Printer | | 8,000 |
| TOTAL | $ 17,240 | $ 22,390 |

Figure 4

As students progress and gain programming experience they will attempt problems which require more and more output. The teletypewriter quickly becomes the system bottleneck. The computer systems presented in figures 1, 2 and 3 will be limited by the teletypewriter's speed. For example, it will require up to 7 minutes to print a page of output on a teletypewriter. Using a 30 character-a-second printer, e.g. the DECwriter, the time is reduced to about 2 minutes. A line printer device, e.g. LP-3000 reduces the time to print a page to seconds. Thus, using a high speed printer the system configured in figure 4 should handle large numbers of student programs. If we include a mixture of simple programming exercises and reasonably complex programs in mathematics, physics, chemistry and statistics this computer system should be able to handle from 300 to 500 programs a day.

The systems presented in figures 3 and 4 work best with interpretive languages such as BASIC. The BASIC interpreter remains in the computer's memory from program-to-program. However, assemblers and compilers, e.g. FORTRAN, must be loaded into the computer with each new program. To alleviate the time consuming process of loading in assemblers and compilers we can add an auxiliary storage device such as magnetic disks or some form of magnetic tape. Depending on the computer manufacturer and the peripheral devices selected, it may be possible to use an operating system. An operating system (sometimes called a monitor) can improve the overall performance by helping to automate some of the manual operating functions in addition to loading the system programs. The computer manufacturers generally tend toward disk operating systems. However, some manufacturers do have operating systems which will work with either magnetic disks or tapes. In general, the hardware requirements for disk based operating systems vary greatly from manufacturer to manufacturer. By way of example, Digital Equipment's monitor requires a minimum of 8K memory and a 32K word disk, while Data General requires 16K memory and the 128K word disk. Figure 5 illustrates an alternative to a disk based operating system using a cassette storage device and a cassette operating system.

Computer,Mark Sense Reader,Printer and Three Tape Cassette system




| | |
|---|---|
| 8 K PDP-8/e with TTY | $9500 |
| Potter LP3000 Printer-135 lpm | 4600 |
| GDI Mark Sense Reader | 3100 |
| DICOM 3 tape cassette system | 6400 |
| TOTAL | $23,600 |

figure 5

The computer system in figure 5 is a powerful computer system with the capacity for handling large numbers of student programs of varying complexity. It could operate in the following manner provided the software is available. One tape cassette will contain all the necessary "system" software, e.g. executive or monitor routines, BASIC, FORTRAN, assemblers, editors, loaders, input-output programs and any other frequently used programs. The student would place his cards in the mark sense card reader and type in commands at the teletype. For example, the student might type in "BASIC" to run a BASIC program. The monitor would search the cassette containing the system programs for the BASIC interpreter and load it into the computer's memory. The cards would then be read, the program run and the results printed out. If the student wanted to do an assembly he would type ASMB." Since the assembler requires three passes (or scans) of the source program, the monitor reads the cards and copies them onto another cassette tape. The monitor searches for and loads the assembler. The assembler makes its three passes over the source on the tape cassette. During the third pass the assembler prints an assembly listing of the program at the printer's speed. The assembler writes the binary object program onto another cassette tape. The student then directs the monitor to load and run his object program. The compilation of a FORTRAN program would follow a similar procedure. At this point at least two of three tape cassette transports are available for use by the program in the computer. For example, students could be asked to perform statistical computations on data recorded on a tape cassette. Several students can be given the same problem or variations of the same problem using the same tape cassette as input data. The tape cassettes can be used to provide realistic problems in data processing such as sorting and merging of files, file updating, etc. Since tape cassettes are easily mounted and dismounted, and are easily locked in a desk drawer, they can be used to keep administrative records such as grades, test scores, attendance records, etc., in complete security. The tape cassettes can be used to store programs and subroutines which the students can retrieve and use. Student programs stored on a tape cassette can be edited on the tape until a correct version is obtained. Thus, an entire class can have all their programs on one or two tape cassettes. Program modification under the BASIC system would be quite simple. The student would call in BASIC, tell it his program's file name, read in the mark sense correction cards and run his program. The BASIC statements on the mark sense cards would be merged with the statements in the student's program, following the normal BASIC rules, then the program would be executed with the results appearing on the printer. The student could direct the monitor to save his new updated program and delete his old copy.

Although the computer priced in figure 5 is a DEC PDP-8/e, Dicom has almost identical cassette tape monitor systems for Data General's Nova 1200 and Nova 800 computers and for Hewlett-Packard's HP-2114C computer. Digital Equipment Corporation also has a monitor system for the PDP-8 computer family called PS-8 (Programming System 8). PS-8 can use either disk or DECtape. Interdata has a monitor system called OS-Loader which will operate with Interdata's Intertape cassette storage devices. The card readers, printer and cassette tapes permit the computing system to be used in a realistic manner by simulating and behaving as a large scale computing system would. This type of a system has many characteristics in common with larger scale computing installations.

Although any of the computers in Appendix B can be substituted for the PDP-8/e in figure 5, the Varian 620/L and the Interdata I4 can lead to systems suitable for commercial and vocational programmer training.

The Varian 620/L will support RPG (Report Program Generator). Although the 620/L-RPG System requires a card punch in addition to a card reader and printer, the RPG software can be modified to output the binary object program on the teletypewriter's paper-tape punch. This will save the cost of a card punch.

RPG is a widely used business and data processing language. It is relatively easy to learn, to program in, and to debug. It is available for almost all of IBM's 360/370 series of machines and on IBM's System 3 computers which are marketed for business applications. Several other large computer manufacturers, such as Control Data, RCA, and Honeywell offer RPG on their computers marketed for business data processing. It is especially useful for those computers which are too small for a COBOL (COmmon Business Oriented Lanugage) compiler.

Since the Varian 620/L also has the BASIC and FORTRAN languages as well as RPG it could be a very suitable choice. This would be especially applicable for those schools which plan to incorporate computer education for their academic and commercial programs. However, there is still another approach which can also provide valuable vocational training. IBM's 360/370 series of computers has been very successful. It would be most advantageous to provide training on a low-cost computer system which would be close to an IBM computer in as many characteristics as possible. The Interdata Model I4 is very close in design principle and architecture to IBM's 360 computers. The differences are in word size (32 bits for the IBM 360 and 16 bits for the I4), base registers, and storage-to-storage instructions. In the smallest of the IBM 360 computers, the IBM 360 model 20, the first two differences with the I4 disappear. Interdata has developed a simulator program for the I4 which will simulate the IBM 360 model 20. This permits the I4 to run programs written for the IBM 360 model 20. Thus, IBM's assemblers RPG and tape sort merge programs can also run on the I4 with it's model 20 simulator. Interdata's simulator, FORTRAN IV compiler, assembler and operating system could make for a viable educational computer system. It could be used to provide computer services for vocational, commercial and academic programs. By including the mark sense card reader, line printer, and Interdata's Intertape cassette storage devices, the computer system would have sufficient processing capacity to handle large numbers of students. The changes in figure 5 to reflect this system are as follows:

| | | |
|---|---|---|
| | Computer - Interdata 4 with 8K words and TTY: | 13,300 |
| | 2 Cassette transports - Intertape: | 2,500 |
| or | 4 Cassette transports - 2x Intertape: | 5,000 |

Using the same card reader and line printer, the system described above would cost $23,500 with two cassette tape transports or $26,000 for four cassette tape transports.

Although the computer systems in figures 1 through 5 reflect some of the ways in which an educational computer system can grow, they do reflect an orientation toward the batch approach rather than a time-sharing approach. The batch approach can handle a sufficient number of student programs and still provide time in which students can be given "hands-on" experience. The configuration in figure 2 is a multiuser system. It too can be extended by adding a card reader, line printer and auxiliary storage devices. Although the hardware interconnections are possible, no software is availabe from any of the manufacturer's for concurrent multiuser and batch operations. However , a combined configuration (say figure 2 and figure 4) could be operated part time as a multiuser system and part time as batch system. The major use of a multiuser (or time sharing) system which is not available to the batch system user is the interactive facility. The interactive facility is useful in CAI (Computer Aided Instruction) or in game playing and simulation situations in which student-machine dialogs take place. In all other aspects, the batch approach can provide for more efficient utilization of the computer.

Conclusions

In a multiuser system, as in time-sharing, the number of students which the computer system can accommodate during a session depends upon the number of teletypewriter terminals available. The cost of expanding beyond four or five users becomes as great as the cost of adding peripheral devices such as card readers and line printers. A batch or single user system is capable of accommodating larger number of students during the same time period. However, the actual number of students handled will depend more upon how fast programs can be entered into the computer and how fast they can print out than upon the computers actual speed. Although manufacturers and salesmen often quote memory or computer speed, it is the combination of computer and software which is of importance. It is the software, i.e. compilers, assemblers, interpreters, editors, operating system, loaders, etc., which will determine how useful a computer system will be. For example, a FORTRAN compiler which does not have good disgnostics (indication of a programming error) will be difficult to use effectively especially for the beginning students. A BASIC interpreter which does not have "string variables" may be a severe handicap to it's educational utility. BASIC appears to have a large following in the secondary schools. This is due to it's wide availability. Through various time-sharing sources and through mini-computer systems. A good deal of secondary school level materials are available from a great many sources - ranging from books to simulation programs available from regional computer education projects. BASIC is easy to learn and simple to use. It is simple enough to be taught to elementary school children yet powerful enough to solve many problems in science and commerce. However, FORTRAN is still favored for scientific and engineering problems in industrial and university environments. FORTRAN is a more powerful and flexible language though more difficult to learn and use. ALGOL (Algorithmic Language), though widely used in Europe, has few followers in the United States, especially at the secondary school level. FOCAL is a language of considerably greater power than BASIC. However, it is available only on D.E.C.'s PDP-8 series of computers. RPG is used in business and commercial applications; it is suitable for small computers, it is also easy to learn and use. However, only Varian and Interdata are the only manufacturers to make it available. It is likely that BASIC will continue to serve as a teaching vehicle for commercial applications in the high school curriculum. Many high school programs in computer education start out with a single language, usually BASIC. Within a year a number of students will be clamoring for assembly language and FORTRAN. Some of them will be so eager to progress that they will learn assembly language on their own. Therefore, it is important to plan on a computer system which will have as great a variety of programming languages as possible.

In choosing the computer itself, consideration should be given to the software available rather than memory cycle time, number of bits in a word, number of registers, and the number of instructions. Another very important consideration in choosing a computer is the availability of maintenance. It is usually preferable to obtain the maintenance directly from the manufacturer rather than from independent sources. Changing a lamp in the computer's display panel may require a maintenance man in most of the minicomputers, so don't plan on doing your own maintenance. In purchasing any options, such as hardware multiply-divide, be sure that the software to be used will actually make use of the purchased option. An option which should be considered is the automatic bootstrap loaders. This will save endless frustration in starting up the computer.

Peripheral equipment in general should be purchased from the computer manufacturer for the sake of maintenance and software support and compatibility. The exception to this general rule is when the computer manufacturer does not offer that type of peripheral, e.g. tape cassette unit, or the manufacturer has only a prohibitively expensive, high performance peripheral device, e.g. line printer. Three types of peripheral devices considered in the study fall under this exception. Mark sense card readers, if not available from the computer manufacturer, are generally compatible with the manufacturer's own card reader. In some instances the computer manufacturer will yield to prodding and supply a mark sense card reader. It is important to be sure of maintenance and adequate software support for the mark sense card reader. Digital Equipment Corporation and Interdata manufacture their own special tape systems. In both cases, the tape systems interface to their respective computers and are fully supported with software, including operating systems. The other cassette tape systems in Appendix C can be electronically connected to any one of a number of minicomputers. However, adequate software is provided for only the more popular minicomputers, as indicated by the last column of appendix C. Here again one must be sure that the level of software support, for a given computer, will be sufficient to utilize the cassette tape system in the intended manner. Both D.E.C. and Interdata will of course maintain their own tape systems; however, with the other cassette tape system manufacturers maintenance may be somewhat more of a problem especially for schools which are distant from major urban areas. Fortunately, however, most of the tape cassette systems seem to be conservatively designed and should provide fairly reliable operation. Those tape cassette systems which are sold through a manufacturer's representative can usually be serviced through the representative. Printing devices also deserve careful consideration. Generally electromechanical equipment such as printers require a high degree of maintenance. However, recent improvements in technology have lead to new printer designs with improved reliability especially in the low and medium speed range. These printers are also significantly lower in cost than older printers. Non impact printers using an ink drop technology such as A.B. Dick's Video Jet Printer or Teletype's Inktronic printer, may be the most suitable for the educational environment. They are quiet, use ordinary paper, inherently reliable, and low cost. Interfaces are available as is software to support them for most minicomputers. Maintenance and service are nationwide and should be available in most communities.

By following the guide lines, considerations and specifications in this report, a highly effective educational computer system can be built in a modular fashion. Planning should be done over a three to five year period so that all of the equipment purchased can be used at each stage of the expansion. The configurations illustrated in the previous section indicate how such expension can take place.

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## APPENDIX A

| MINICOMPUTER MANUFACTURERS | MODEL | MINIMUM SYSTEM COST (1) |
|---|---|---|
| 1. Atron Corp.<br>1256 Trapp Road<br>St. Paul, Minn. 55118<br>612-454-6150 | Atron-501 | $ 7,600 |
| 2. BIT, Inc.<br>5 Strathmore Road<br>Natick, Mass. 01760<br>617-237-2930 | BIT 483 | 11,700 |
| 3. Cincinnati Milacron, Inc.<br>Process Control Div.<br>Lebanon, Ohio 45036<br>513-949-5444 | CIP 2100 | 7,815 |
| 4. Clary Datacomp Systems, Inc.<br>404 Juniper Serra Drive<br>San Gabriel, Calif. 91776<br>213-283-9485 | DATACOMP 404 | 9,950 |
| 5. Compiler Systems, Inc.<br>P. O. Box 366<br>Ridgefield, Conn. 06877<br>203-438-0488 | CSI-16<br>CSI-24 | 10,750<br>17,250 |
| 6. Computer Automation, Inc.<br>895 West 16th Street<br>Newport Beach, Calif. 92660<br>714-642-9630 | Model 116<br>Model 216<br>Model 816 | 11,990<br>9,980<br>7,990 |
| 7. Computer Logic Systems, Inc.<br>49 Pollard Street<br>North Billerica, Mass. 01862<br>617-729-2703 | CLS-18 | 10,950 |
| 8. Data General Corp.<br>Route 9<br>Southboro, Mass. 01772<br>617-485-9100 | NOVA 1200 *<br>NOVA 800 *<br>SUPER NOVA | 6,700<br>8,200<br>10,850 |
| 9. Datamate Computer Systems, Inc.<br>P. O. Box 310<br>Big Spring, Texas 79720<br>915-267-6353 | Datamate 16<br>Datamate 70 | 16,600<br>10,200 |

| | | | |
|---|---|---|---|
| 10. | Digital Computer Controls<br>23 Just Road<br>Fairfield, New Jersey 07006<br>201-227-4861 | D-112IA | $ 5,200 |
| 11. | Digital Equipment Corporation<br>146 Main Street<br>Maynard, Mass.<br>617-897-5111 | PDP-8/L<br>PDP-8/i<br>PDP-8/e *<br>PDP-11/20 * | 8,500<br>12,800<br>6,490<br>10,800 |
| 12. | Digital Scientific Corp.<br>11455 Sorrento Valley Road<br>San Diego, Calif. 92121<br>714-453-6050 | Meta-4 | 15,650 |
| 13. | Electronic Associates, Inc.<br>185 Monmouth Pk. Hwy.<br>West Long Branch, N. J. 07764<br>201-229-1100 | EAI-640 | 24,000 |
| 14. | Elron, Inc.<br>Bldg. 812, Raritan Ctr.<br>Edison, N. J. 08811<br>201-225-1900 | ELBIT-100 | 6,600 |
| 15. | Foto-Mem, Inc.<br>2 Mercer Road<br>Natick, Mass. 01760<br>617-655-4600 | CENTAUR | 12,000 |
| 16. | General Automation, Inc.<br>1402 E. Chestnut Avenue<br>Santa Ana, Calif. 92701<br>714-835-4804 | SPC-16<br>SPC-12 | 11,250<br>9,700 |
| 17. | GRI Computer Corp.<br>96 Rowe Street<br>Newton, Mass. 02166<br>617-969-0800 | GRI-909 | 8,400 |
| 18. | Hewlett-Packard Co.<br>Cupertino Division<br>11000 Wolfe Road<br>Cupertino, Calif. 95014<br>408-257-7000 | HP2114C *<br>HP2116C | 10,500<br>22,000 |
| 19. | Honeywell Computer, Control Div.<br>Old Connecticut Park<br>Framingham, Mass. 01701<br>617-235-6220 | H-316 * | 10,400 |

| | | | |
|---|---|---|---|
| 20. | Information Technology, Inc.<br>164 Wolfe Road<br>Sunnyvale, Calif. 94086 | ITI 4900 | $ 11.150 |
| 21. | Infotronics Corp.<br>8500 Cameron Road<br>Austin, Texas 78753<br>512-454-3521 | mini/max | 14,400 |
| 22. | Interdata, Inc.<br>2 Crescent Place<br>Oceanport, N. J. 07757<br>201-229-4040 | I 4 * | 10,100 |
| 23. | Lockheed Electronics<br>Data Products Div.<br>6201 E. Randolph St.<br>Los Angeles, Calif. 90022<br>213-722-6810 | MAC 16jr | 9,500 |
| 24. | Microdata Corp.<br>644 East Young St.<br>Santa Ana, Calif. 92704<br>714-546-7160 | MICRO 810 | 9,415 |
| 25. | Modular Computer Systems, Inc.<br>2709 N. Dixie H'way<br>Fort Lauderdale, Fla. 33308<br>305-563-4392 | Modcomp II | 11,500 |
| 26. | Motorola Instrumentation & Control<br>3102 North 56th Street<br>Phoenix, Ariz. 85030<br>602-959-1000 | MDP-1000 | 9,250 |
| 27. | Multidata, Inc.<br>7300 Bolsa Avenue<br>Westminster, Calif. 92683<br>213-598-1377 | Mod A | 15,000 |
| 28. | Philips Business Systems, Inc.<br>100 East 42nd Street<br>New York, New York 10017<br>212-697-3600 | P-350 | |
| 29. | Raytheon<br>2700 South Fairview St.<br>Santa Ana, Calif. 92704<br>714-546-7160 | 703<br>704 * | 13,950<br>10,950 |

| | | | |
|---|---|---|---|
| 30. | Redcor Corp., Inc.<br>21200 Victory Blvd.<br>Woodland Hills, Calif. 91364<br>213-348-5892 | RC 70 | $ 16,400 |
| 31. | Spiras Systems, Inc.<br>332 Second Avenue<br>Waltham, Mass. 20154<br>617-891-7300 | SPIRAS-65 | 14,600 |
| 32. | Systems Engineering Labs.<br>6901 West Sunries Blvd.<br>Fort Lauderdale, Fla. 33301<br>305-587-2900 | SEL 82<br>SEL 72 | 9,600<br>15,000 |
| 33. | TEC, Inc.<br>6700 South Washington Ave.<br>Eden Prairie, Minn. 55343<br>612-941-1100 | 520-PCP | 13,490 |
| 34. | Tempo Computers, Inc.<br>1550 So. State College Blvd.<br>Anaheim, Calif. 92806<br>714-633-3660 | TEMPO 1 | 15,600 |
| 35. | Texas Instruments<br>P. O. Box 66027<br>Houston, Texas 77006<br>713=526-1411 | TI-960 | 15,460 |
| 36. | Unicomp, Inc.<br>18219 Parthemia St.<br>Northridge, Calif. 91324<br>213-886-7722 | Comp-16 | 9,300 |
| 37. | Varian Data Machines, Inc.<br>2722 Michelson Drive<br>Irvine, Calif. 92664<br>714-833-2400 | 620/L *<br>620/i<br>620/f | 7,200<br>11,750<br>12,400 |
| 38. | Viatron Computer Systems Corp.<br>Route 62<br>Bedford, Mass. 01730<br>617-275-6100 | 2140/50 | |
| 39. | Westinghouse<br>Computer Department<br>1200 West Colonial Drive<br>Orlando, Fla. 32804 | 2500 * | 11,850 |

| | | | |
|---|---|---|---|
| 40. | Xerox Data Systems<br>701 South Aviation Blvd.<br>El Segundo, Calif.<br>213-772-4511 | CE-16A | $ 13,000 |
| 41. | Wang Laboratories<br>836 North Street<br>Tewksbury, Mass. 01876<br>617-851-7311 | Wang 3300 | 9,700 |

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* Minicomputer models followed by an asterisk indicate that it is considered acceptable for an educational computing environment.

(1) A minimum system consists of a computer processor, 4096 words of memory, and a console teletypewriter with integral paper tape reader and punch operating at 10 characters per second. The costs were compiled from manufacturer supplied price lists and are current as of the last quarter 1970 and January 1971.

## APPENDIX B

Some characteristics of the acceptable minicomputers

| Machine | Bits Per Word | Cycle* Time | No. of Accumulators | No. of Index Registers | Add Time* | BASIC | Multiuser System | Cost of 4K Storage (Additional) | Min. Storage for FORTRAN |
|---|---|---|---|---|---|---|---|---|---|
| Nova 1200 | 16 | 1.2 | 4 | 2H/16M | 1.35 | Yes | BASIC | $ 2,700 | 8K |
| Nova 800 | 16 | 0.8 | 4 | 2H/16M | 1.8 | Yes | BASIC | 3,000 | 8K |
| PDP-8/e | 12 | 1.2 | 1 | 8M | 2.6 | Yes | BASIC/ FOCAL | 3,000 | 4K and 8K |
| PDP-11/20 | 16 | 1.2 | 8 | 7H | 2.3 | Yes | BASIC | 3,500 | 8K |
| I4 | 16 | 1.0 | 16 | 15H | 3.2 | No | FORTRAN | 3,200 | 8K |
| HP2114C | 16 | 2.0 | 2 | NONE | 4.0 | Yes | BASIC# | 4,500 | 8K |
| H316 | 16 | 1.6 | 2 | 1H | 3.2 | No | NO | 3,500 | 8K |
| 704 | 16 | 1.5 | 1 | 1H | 2.0 | No | No | 4,000 | 3K |
| 620/L | 16 | 1.8 | 2 | 2H | 3.6 | Yes | No | 2,300 | 8K |
| 2500 | 16 | .75 | 2 | 2H | 2.0 | Yes | No | 4,500 | 8K |

*- Time is given in units of microseconds. One microsecond = $10^{-6}$ seconds.

H- Actual hardware index registers. M- Memory locations used as index registers

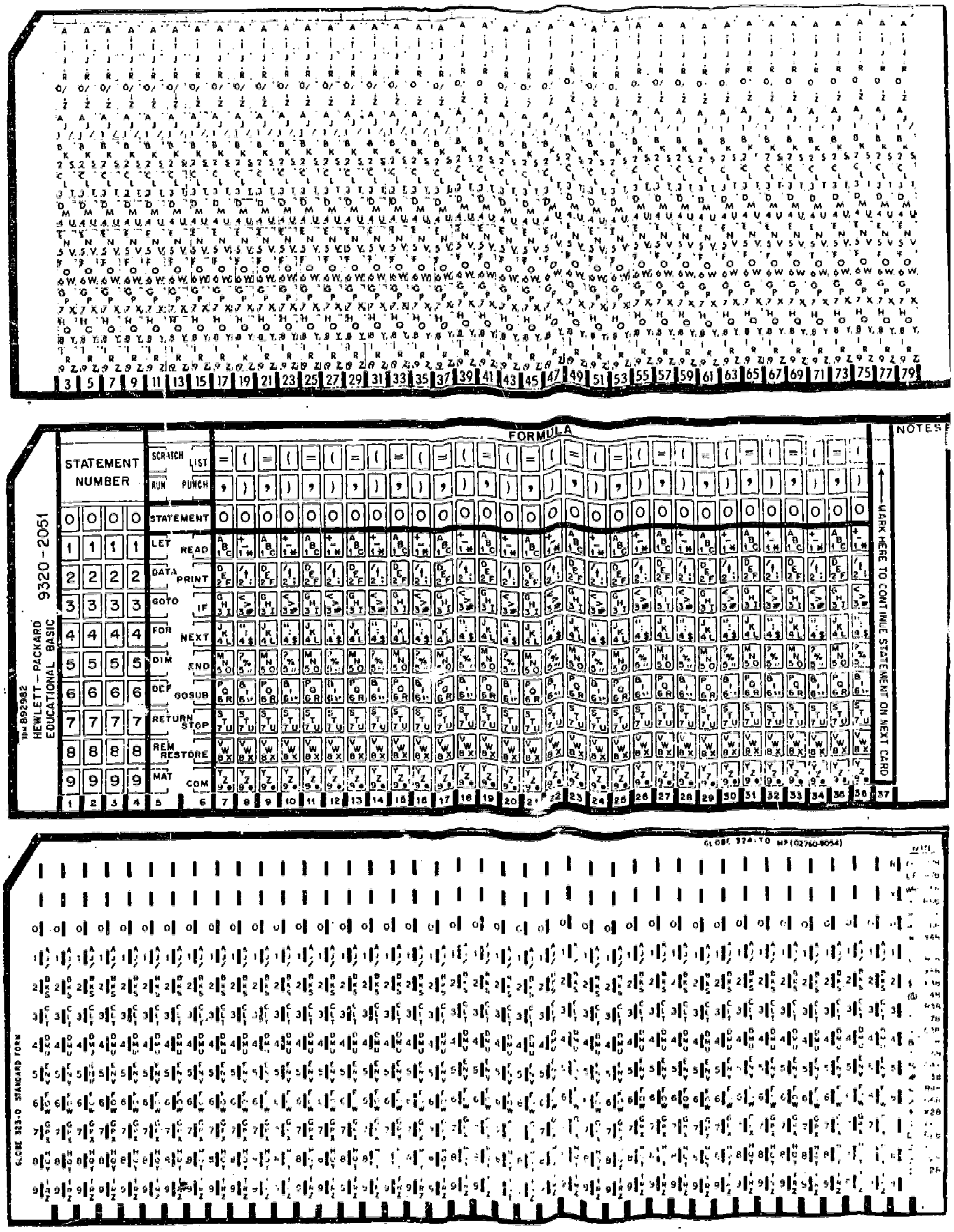
K- One K equals 1024. Thus 8K = 8(1024) = 8192

#- The BASIC multiuser system is available from Hewlett-Packard, but it is not part of their standard software.

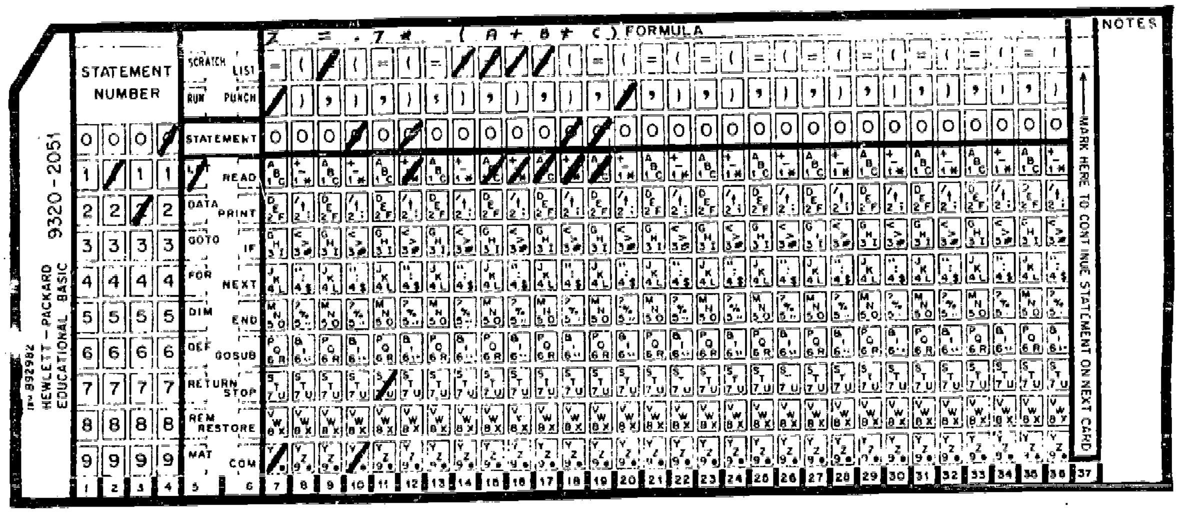
# APPENDIX C

| Manufacturer | Model | Approx. Price | No. of Drives | Interface and Software for |
|---|---|---|---|---|
| DICOM Industries<br>715 N. Pastoria Avenue<br>Sunnyvale, Calif. 94086 | 344 CTMOS | $7250 | 3 | DEC PDP-8 series<br>HP 2114<br>NOVA 1200/800 |
| Digital Equipment Corp.<br>146 Main Street<br>Maynard, Mass. 01754 | TC08<br>Controller<br>TU56H DECtape Drive | 5900<br><br>2350 | 1 - 8 | PDP-8 |
| Interdata<br>2 Crescent Place<br>Oceanport, N. J. 07757 | Intertape | 2500 | 2 | I 4 |
| SYKES Datatronics, Inc.<br>375 Orchard Street<br>Rochester, N. Y. 14606 | Compu/corder<br>100 | 2950 | 1 | PDP-8 series<br>NOVA 1200/800<br>Varian 620/L |
| Tennecomp Systems<br>795 Oak Ridge Turnpike<br>Oak Ridge, Tenn. 37830 | TP-1351 | 2000 | 1 | PDP-8 series |
| Tri-Data Corp.<br>800 Maude Avenue<br>Mountainview, Calif. 94040 | Cartrifile<br>4196 | 6500 | 4 | PDP-8 series<br>HP 2114<br>NOVA 1200/800 |

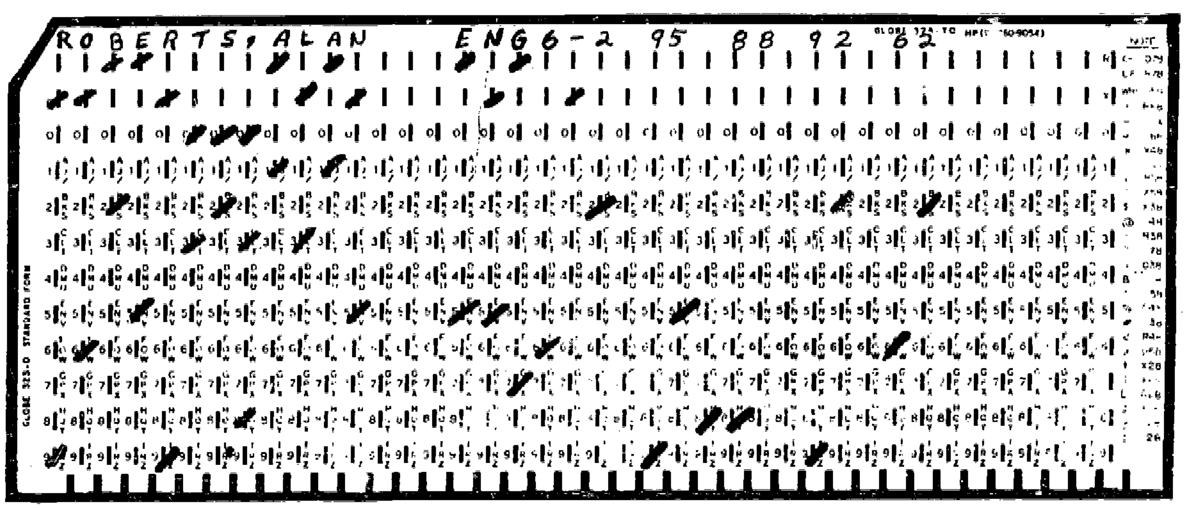
APPENDIX D-1



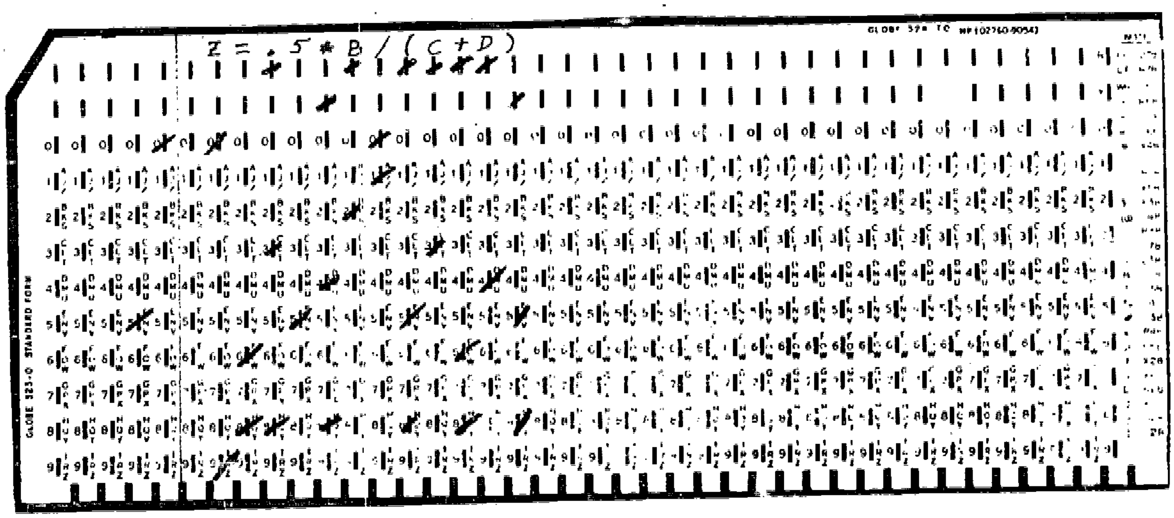

Blank Mark sense card forms (size reduced by 75%)



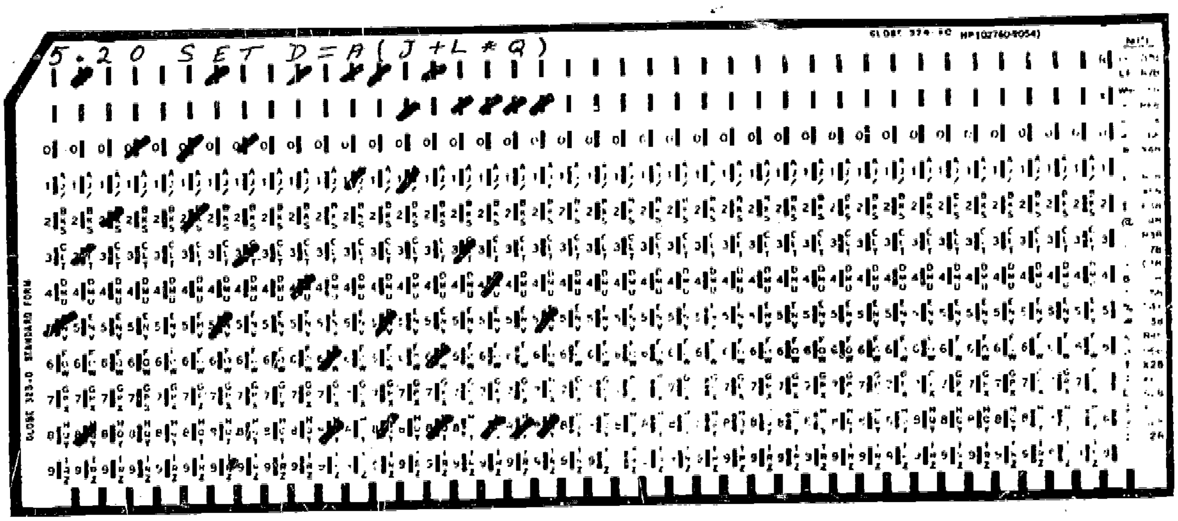
BASIC: 120 Let Z = .7 * (A + B * C)
Special purpose mark sense card used in the Hewlett-Packard Educational System 2007A



A multipurpose mark sense card in a grade reporting application.




General Purpose Mark Sense Card
FORTRAN Statement: 50 Z = .5 * B/(C+D)




General Purpose Mark Sense Card
FOCAL Statement: 5.20 SET D=A (J+L*Q)

# APPENDIX E

## Mark Sense (Optical) Card Readers

| Manufacturer | Model | Approximate Cost | Reader Rate* |
|---|---|---|---|
| General Design, Inc. (GDI)<br>2361 NASA Boulevard<br>Melbourne, Florida 32901 | GDI-100-MS | $ 2500 exclusive of interface | 200 cpm |
| Hewlett-Packard<br>Cupertino Division<br>11000 Wolfe Road<br>Cupertino, Calif. 95014 | HP2761A | 3700<br>interfaced<br>to HP2114C | 200 cpm |
| Motorola<br>Instrumentation and Control, Inc.<br>P. O. Box 5409<br>Phoenix, Arizona 85010 | MDR-8000 | 4500<br>exclusive of<br>interface | 150 cpm |
| Digital Equipment Corporation<br>146 Main Street<br>Maynard, Massachusetts 01754 | CM8-E # | 4900<br>interfaced<br>to PDP-8/e | 200 cpm |

* Reader rate in cards per minute (cpm)

\# The CM8-E is manufactured by GDI

## APPENDIX F

### Low Cost Output Devices

| Manufacturer | Model | Speed* | Characters/line | Cost |
|---|---|---|---|---|
| I -includes keyboard | | | | |
| Teletype Corporation# | KSR33 | 10cps | 72 | $650 |
| | ASR33 | 10cps | 72 | $800 |
| IBM Corporation | 2740/41 | 15cps | 121 | $3500 |
| SYNER DATA<br>133 Brimbal Ave.<br>Beverly, Mass.01915 | Beta | 10/15/30cps | 132 | $6000 |
| REPCO, Inc.<br>1940 Lockwood Way<br>Orlando, Fla. 32804 | 120 | 120cps | 80 | $2500 |
| Sperry Rand UNIVAC | DCT-500 | 30cps | 132 | $4500 |
| Digital Equipment Corp. | LA-30 | 30 cps | 80 | $2500 |
| Texas Instruments, Inc. | 710 | 15/30cps | 80 | $3800 |
| General Electric | 300 | 10/15/30cps | 75 | $3700 |
| Litton,ABS Div. | 30 | 25cps | 192 | $2200 |

This is not a complete list of Keyboard-printing devices. However, it is representative of the many other similar devices.

*cps - characters per second or lps - lines per second.

# Virtually all minicomputers have a standard interface to the teletype ASR(KSR) 33. The ASR33 includes a paper-tape reader/punch and is used as the standard input-output device. Teletypes supplied by the computer manufacturer usually will be slightly more expensive.

| Manufacturer | Model | Speed | Char./line | Technology | Cost |
|---|---|---|---|---|---|
| II Printers | | | | | |
| Centronics<br>Hudson, N.H. | 101 | 165cps | 132 | impact | $2500 |
| Data Printer<br>Cambridge, Mass. | F80<br>F132 | 600lpm<br>600lpm | 80<br>132 | impact<br>impact | $8000<br>$11000 |
| A.B. Dick<br>Chicago, Ill. | Videojet 960 | 250cps | 132 | ink jet | $7500 |
| Mortec<br>Ashland, Mass. | B64 | 200lpm | 132 | impact | $6500 |
| Odec Computer Systems<br>East Providence, R.I. | 801 | 150 | 80 | impact | $6500 |
| Potter Instruments Co.<br>Plainview, N.Y. | LP-300 | 300cps/135lpm | 132 | impact | $4500 |
| Teletype Corp.<br>Skokie, Ill. | Inktronic | 120cps | 80 | ink jet | $5500 |
| Vogue Instruments<br>Richmond Hill, N.Y. | 880c | 400lpm | 80 | impact | $9800 |
| Versatec<br>Cupertino, Cal. | Matrix 300 | 300lpm | 80 | electro-static | $6000 |
| SYNER DATA<br>Beverly, Mass. | ALPHA | 300lpm | 80 | impact | $2000 |

This is not a complete list of available equipment but represents those printing devices which the author feels will best service the educational environment.

## Glossary of Commonly Used Computer Terminology

This glossary contains only the most commonly encountered terminology. It should be helpful to those with little or no background in computer technology and who will deal with minicomputer manufacturers and their sales personnel. A more comprehensive listing of computer terminology can be found in "Vocabulary for Information Processing," published by the American National Standards Institute, Inc., 1430 Broadway, New York, New York, 10018.

Absolute Address (or coding) - An address (or coding, i.e. machine instructions) written or expressed in the basic numeric language acceptable to the computer without any further modification.

Access Time - The time duration required to obtain information from a storage device (read time) or the time duration to place information into a storage device (write time).

Accumulator - A part of the arithmetic logic unit of a computer. It is a register which temporarily stores information and is used to perform manipulation upon the information such as summing it with a second quantity. The accumulator may also be used in the transfer of data to and from storage or external devices.

Accoustic Coupler - A device used to transfer information to and from a terminal (e.g. teletypewriter) via an ordinary telephone set over telephone lines to a remote computer. An accoustic coupler may be used in place of a data set to provide portability to the terminal.

Adder - A device (a part of the arithmetic-logic unit of a computer) capable of forming the sum of two or more digital quantities. The device whose function is implied in an add instruction.

Address - A label, name or number which designates a register, memory location or device. An address may be either absolute or symbolic, it may be direct or may require further modification. It may refer to data or to an instruction or to a device.

Address Modification - The process or means of changing an address part of an instruction for actual use by the machine. The types of address modification are as follows:

1. Direct: no modification of address
2. Indexed: adding an index value (or the contents of an index register) to the specified address.
3. Indirect: the actual address used by the instruction is taken from the location specified in the address part of an instruction.
4. Relative: the address is relative to the value contained in some register.

ALGOL - ALGOrithmic Language. A computer language allowing the programmer to communicate with the computer using a mathematics-like notation. ALGOL is similar to other programming languages such as JOSS, FOCAL, BASIC and FORTRAN.

Algorithm - A finite set of step-by-step rules or procedures for the solution of a given problem (assuming that a solution is possible). The rules for long division or a computer program which gives consistent answers, are examples of algorithms.

Alphanumeric - Characters which consist of the letters of the alphabet, numerals and/or special symbols which are represented in some form for use in and manipulation by the computer.

Analog Computer - A computer which uses physical quantities (e.g. voltage, force, fluid volume) to represent numeric quantities in performing computation.

Arithmetic Unit - That functional part of the computer involved in arithmetic and logical operations such as addition, subtraction, multiplication, address modification, shifting, etc.

ASCII - American Standard Code for Information Interchange. A standard established to represent alphanumeric characters in computers and for the interchange and communication of computer intelligent information. ASCII has been adopted by almost all minicomputer manufacturers.

Assembler, Assemble - A computer program that operates on a symbolic input (assembly language program) to assemble or produce machine instructions. The assembler, assembles or translates the symbolic instructions of the program into machine instructions. The assembler is the most basic program supplied by the manufacturer.

Assembly language - This is the most elementary (but most difficult to learn and use) symbolic language of the computer. Assembly language is translated by the assembler into machine instructions which the computer may execute.

Automatic programming - The approach or process of using the computer to perform some of the work and effort in preparing a computer program to solve a problem.

Auxiliary storage - Storage (or memory facility) which supplements the computers main memory. Auxiliary storage is usually provided by means of magnetic tape or magnetic disk or drum device.

Base - A number base, a quantity used implicity to define a system of representing numbers by positional notation, also termed Radix.

Ordinary numbers use base 10 or decimal notation, while computers generally use base 2 or binary notation. The octal or base 8 notation is also frequently encountered.

Base page - Minicomputers generally have their main memories divided into units termed pages. The pages are numbered sequentially and each page contains a fixed number of storage locations. The lowest numbered page is called the base page or page zero.

BASIC - Beginner's All-purpose Symbolic Instruction Code is a programming language developed at the Dartmouth College. It uses an English and Mathematics like notation. It is an easy to learn and use programming language and has been widely accepted. A good deal of secondary school curriculum materials have been developed using BASIC.

Baud - A baud is a unit of information transmission. In data communications it refers to the number of bits (pulses) transmitted per second. A teletypewriter is a 110 baud device, that is, it can transmit or receive information at the rate of 110 bits per second.

Batch Processing - Is a mode of operating a computer system in which all the resources of the computer are available to a single program until that program is completed. The next program can begin only when the prior program is completed. This is in opposition to timesharing in which a number of programs, in various states of completion, are competing for or sharing the computer's resources.

Binary - A positional number system employing the base two representation. The binary digits are 0 and 1. Most minicomputers employ the binary number system for representing numbers. Machine instructions (language) are in binary form; that is, composed of 0's and 1's.

Binary device - Any device capable of having two distinguishing states is termed a binary device. Examples are a hole or no hole. (In a punch card or paper tape), voltage or no voltage (in an electronic circuit), a switch either on or off.

Bit - A contraction of Binary Digit. Sometimes used to denote the binary digit of "1".

Boolean - Generally in reference to the logical operators of AND, OR and NOT with respect to binary values.

Bootstrap - A short sequence of instructions, manually entered into the computer's memory which enables it to operate a device (usually paper tape reader) which will read into the computer's memory a larger program - usually called a loader. Some manufacturers call the bootstrap a RIM loader.

Branch - An instruction which causes the computer to switch from one sequence of instructions to another sequence of instructions. A branch may be an unconditional branch or the branch may occur only when specified conditions arise. Some computer manufacturers use the terms "jump" or "transfer" instead of branch.

Buffer - A storage device used when transmitting data between a computer and a device to compensate for a difference in rate of flow of data.

Bus - A path or channel along which data or control signals can be sent. A memory bus is the path from the memory to the computer processor itself. An I/O (input-output) bus can be a path from a magnetic tape device to memory.

Byte - The smallest sequence of bits (binary digits) which may be operated upon as a unit. A byte may also represent a character (usually six or eight bits).

CAI - Computer Aided Instruction or Computer Assisted Instruction; Generally it refers to the use of the computer interactively with the student to provide him with drills, tutorials and problem solving.

Call - To transfer control, temporarily, to a defined sequence of computation steps (a subroutine).

Calling Sequence - A basic sequence of instructions used to begin, initialize, transfer to and/or return from a subroutine.

Carry - The digit, or signal, which occurs when the sum, or product, of two digits equal or exceed the number base.

Central Processor Unit - That part of a computer system which consists of the arithmetic-logical unit, control unit, input-output control and memory. The central processor unit is conveniently abbreviated to CPU.

Channel - A path along which electrical signals can travel between points, e.g. between a device and memory. The terms channel and bus are used in similar ways.

Character - One of a set of elements (digits, letters or special symbols) which may be arranged into groups to convey information. Each character may be represented by a unique group of binary digits such as in the ASCII code.

Clear - Reset to an initial condition or state. To clear memory is to reset memory to it's initial state of all zeros.

Clock - A computer device which generates periodic signals. The clock may be used to synchronize internal operations of the computer.

Closed Shop - A mode of operating a computer system wherein the programmer may only submit his programs to the machine's operator. The programmer is not permitted to exercise physical control over the computer.

CMI - Computer Managed Instruction. In CMI, the role of the computer is to assist the teacher in planning individualized instructional sequences.

Code - 1) The representation of one set of symbols by another e.g. ASCII is a binary code for letters, numerals, etc.

2) Sequences of computer instructions which performs some action or computation.

Coding - To prepare a set of computer instructions to accomplish an action, task or computation. Coding may be absolute (to be used without modification) or symbolic. Also, a sequence of computer instructions.

Compiler, Compile - To prepare a machine language program from a symbolic language program by means of a computer program called a compiler. The compiler allows for the automatic translation of symbolic expressions, understanable by human beings, to sequences of instructions intelligible to the computer.

Computer - A device or instrument capable of accepting and storing information, applying a sequence of prescribed processes to that information, and making the results of those processes available.

Configuration - A particular assembly of a computer, memory input-output devices, and storage devices.

Connect Time - With respect to time-sharing, it is the elapsed time of use, from the time of connecting with the time-sharing computer, to the time of disconnecting.

Contents - The information contained in a storage location.

Control Panel - That part of the computer which contains indicator lights and switches, upon which the computer's operator may direct and interact with the computer.

Control Unit - The portion of a computer which directs (controls) the automatic operation of the computer, controls the flow of information, interprets instructions, and initiates control signals to other portions of the computer in executing instructions.

Controller - The device actually responsible for the operation (e.g. starting, rewinding, reading, etc.) of an input-output device such as magnetic tape. The controller receives it's instructions from the computer and directs and controls the operation of the specified device. A controller can usually control several devices of the same type.

Core Memory - A fast, random-access storage device of the central processing unit; usually made of many small ferromagnetic rings (cores) strung on wires in a matrix of arrays.

CPU - Central Processing Unit - see entry for central processing unit.

Crash - Refers to a computer or program failure which prevents further or continued normal operation.

Current Page - In computers which have their memories divided into pages, it refers to the memory page which contains the current instruction being executed.

Cycle - 1) A sequence of operations regularly repeated.

2) The time it takes for one sequence of occur, i.e. cycle time.

Cycle Stealing - When a device prevents the CPU from reading or writing into memory, so that it can read or write memory itself.

Data - A collection and representation of information and facts by alphabetic and numeric characters, which can be processed or produced by a computer.

DATA-PHONE - A trade mark of the Bell System for the data sets they manufacture and supply. DATA-PHONE service is the Bell System service mark for the transmission of data over the regular telephone network.

Data set - A device which permits a terminal to receive and transmit information over telephone lines. Data sets, generally, are not portable.

Debug - To locate and to remove errors (bugs) or mistakes in a computer program.

Diagnostic - A program or series of programs supplied by the computer manufacturer, used to detect, identify and locate malfunctions in the computer itself and attached input-output devices.

Direct Memory Access - A means (or feature) which permits the direct transferring of blocks of data between an external storage device and the computer's memory. DMA is the commonly used abbreviation for direct memory access. Some computer manufacturers include DMA in their basic price while others will supply DMA at additional cost. DMA is necessary for devices such as magnetic tape drives or disk drive systems.

Disc/Disk - A magnetically coated platter (disk) for the storage of information. A removable disk is termed a diskpack. A disk will require a device called a "controller" for operation with a minicomputer. Generally DMA will also be required.

Double Precision - Data requiring two adjacent memory locations (or words) to gain greater accuracy than would be available from a single word or location.

Downtime - The time during which the computer system is unavailable for use because of equipment malfunction. Downtime is a measure of the reliability of the computer system. As a general rule the larger and more complex a computer system is, the greater will be it's expected downtime.

Driver - An input-output program to provide for automatic operation of a specific device with the computer.

Drum - A cylindrical device, magnetically coated, used to provide auxiliary storage for a computer. A drum is similar to the disk.

Dump - To record the contents of the computer's main memory onto an external device such as a printer or magnetic tape.

Duplex - A communications link which permits two-way operation.

1. Full duplex: two-way communication simultaneously
2. Half duplex: Communication one-way or the other, but not both ways simultaneously.

Effective Address - The address that is derived by applying any specified indexing or indirect addressing rules to the address part of the instruction. The effective address is the address of the location actually used by the instruction.

Enable - To set a signal or condition which will permit a specified event to proceed, whenever it is ready to do so.

Error - The difference in value between a computed or measured quantity and it's known or theoretically correct value.

Execute - To carry out or perform a specified operation such as an instruction or program.

Execute Cycle - A state of the internal logic which causes the computer to carry out a sequence of elementary steps to produce the results specified by the instruction.

Execution Time - The length of time the computer is actually processing the user's program. With respect to time-sharing, the execution time will generally be a fraction of the connect time.

Executive Control Program - A main system program designed to establish priorities, process and control the execution of other programs. It provides a degree of automation to the operations and management of a computer system. It is also synonymous with monitor, operating system, and supervisory control program.

File - An organized collection of related information items to be treated as a unit. A program, the student attendance records, or an inventory list are examples of files.

Fixed-Point - A numerical representation or arithmetic system in which the radix (fractional) point always appears in a constant, predetermined position.

Flag - An indicator of a signal or condition recognized by the computer e.g. printer ready flag. A flag will generally be in one of two states (binary) - set or reset, on or off.

Floating-Point - A numerical representation and system of arithmetic in which quantities are expressed by a fraction (mantissa) and some power of the radix (exponent or characteristic). Thus the implied radix point may be shifted by adjusting the exponent. Minicomputers do floating point arithmetic by software rather than by hardware, although some have floating point hardware.

Flow Chart - A graphical representation of an algorithm or procedure in which symbols are used to represent individual operations. The lines interconnecting the symbols, represent the flow of information.

FOCAL - Formula Calculator. A proprietary language developed by Digital Equipment Corporation for use on their PDP-8 series of computers. FOCAL is similar to BASIC but has greater capabilities.

Format - A predetermined arrangement of bits, characters and groups of characters into a specified pattern.

FORTRAN - Formula Translator. A programming language developed to express numerical problems with an algebra-like notation. If a FORTRAN compiler exists for a minicomputer, it generally requires at least 8,192 storage locations and operates in single-user batch mode.

Frame - The recording position across the width of paper tape, perpendicular to the direction of it's travel.

Full duplex - See entry for duplex.

Gap - An interval in space or time associated with the processing of data. A gap may be used to separate units of data (records) or to signal the end of a group of data units (file).

Garbage - The production or recording of unwanted and meaningless information in some memory or storage area.

General Purpose computer - A computer designed to handle a wide variety of problems by means of programs stored in it's memory.

Half-duplex - See entry for duplex.

Hardcopy - Refers to any computer generated output which can be meaningfully interpreted by humans. Most commonly it refers to printed output.

Hardware - Physical equipment, mechanical, magnetic, and electronic devices which compose the computer system. Hardware is in contrast to software (computer programs).

Head - The electromagnetic device which writes, reads or erases data on magnetic recording devices such as a disk, tape or drum.

Heuristic - An intuitive approach to problem solving in which an evaluation of the progress made toward the desired result is used in discovering the solution.

Hexadecimal - A positional number system employing the base 16. The hexadecimal digits are represented by 0 through 9 and A, B, C, D, E, F.

High Level Language - Any programming language capable of expressing an algorithm or procedure more concisely than assembly language. BASIC, ALGOL, and FORTRAN are common examples of high-level language.

Hollerith - A 12-bit character code for recording information on punch cards.

Index Register - A memory device containing an index value for modifying an instruction address prior to or during the instructions execution.

Initialize - To set registers, switches and memory locations to prescribed starting values.

Input - The data or information supplied to the computer for processing. A device containing data for input to the computer is termed an input device.

Instruction - A set of bits which cause the computer to perform a specified operation. An instruction consists of three parts: an operation code, an address part and address modifiers.

Interface - A common boundary between two devices having different function. The interface may be as simple as a connector plug or a complex device in itself.

Interpreter - A program for a user language (e.g. BASIC or FOCAL) translation, which translates and executes each statement before translating and executing the next one.

Interrupt - A hardware feature which allows the computer to break its normal sequence of instructions, in such a way that it can resume later, to process data that requires its immediate attention.

I/O - An abbreviation for input-output, i.e. transmission to and from the computer. Also refers to devices such as a teletypewriter.

K - Signifies the prefix "Kilo" meaning a thousand. When used in connection with computers it denotes 1024 rather than 1000. Thus, a 4K memory implies 4 x 1024 or 4096 memory locations.

Label - An arrangement of alphanumeric symbols, used symbolically to identify an instruction, a group of instructions, a program statement, a quantity, a data area, or a program.

Language - A set of symbols, rules and conventions for combining symbols, used to generate statements for the purpose of conveying information. A programming language is used to express algorithms or procedures for use by a computer.

Library - A collection of commonly used programs, such as a SINE program. The computer manufacturer may supply a basic library of programs and the users will contribute additional programs.

Line Printer - A printing device capable of printing an entire line of characters all at once. A teletypewriter prints one character at a time and hence is not a line printer.

Linkage - A means of connecting and communicating information between two separate programs.

Load/Loader - To read into memory a binary program under the control of a loader program.

Location - Refers to a position in storage (or memory) uniquely specified by an address. A location, usua-ly, is a full computer word.

Logical - Pertains to the boolean algebra with the operations "AND", "OR", "NOT" and the values "TRUE" and "FALSE". All minicomputers include logical operations in their capability.

Loop - A sequence of instructions whose execution is repeated a specified number of times.

Machine - Referring to the computer.

Machine language - The most elementary binary language which contains no symbolic information. Machine language is directly acceptable to the machine. See entry for absolute.

MACRO - An advanced assembly language feature which can generate many machine-language instructions from a single MACRO instruction.

Magnetic core - See entry for core memory.

Magnetic Disk/Drum - See entries for Disk and Drum.

Magnetic tape - A widely used storage medium, consisting of a magnetically coated plastic tape. It is similar to the magnetic tape used in home tape recorders.

Mainframe - Refers to the computer CPU as distinct from any associated peripheral equipment.

Maintenance - The necessary support to keep the computer (also large programs such as compilers) in good working order. A separate maintenance contract is usually required for purchased equipment while rental or lease prices usually include maintenance.

Mark sense - A means of recording information on a media, such as a punch card, with a pencil or marking device, as opposed to punching holes in a card. Also pertains to the device capable of reading from mark sense media.

Memory - A device for storing information in a form that can be accessed by the computer hardware.

Memory cycle time - The minimum length of time between two successive access to the memory device.

Memory Protect - See entry for Storage Protect

Minicomputer - A small scale, general purpose digital computer with a word length of from 12 to 18 bits, the most common length being 16 bits. A major characteristic of minicomputers is their low price, less than $10,000 for the CPU. In many respects they are very similar to their larger cousins.

Mnemonic - Abbreviations, for the symbolic instructions of the computer, designed to assist human memory.

Mode - Refers to the method of operations: time-sharing vs batch, open-shop vs closed-shop, fixed-point vs floating point, etc.

Modern - Synonymous with data set, see entry for Data Set.

Monitor - See entry for Executive control program.

Multiplexor - A device for sampling several input (output) channels and interleaving their signals on a single output (input) channel. A multiplexor may give the appearance of simultaneous communications, as in time-sharing.

Normalize - A computer operation which automatically shifts left so that a maximum number of bits are accommodated in a specified register or location. The normalize operation is usually associated with floating-point arithmetic.

Object Code - The absolute or binary output of a compiler or assembler, as opposed to a source or symbolic program. The object code is in a machine language form.

Octal - A positional number system employing base 8. Binary numbers are easily expressed as octal numbers by expressing successive groups of three binary digits as a single octal digit.

OEM - Original Equipment Manufacturer: the manufacturer who supplies equipment to be included in a second manufacturers product line. For example, the Teletype Corp. is the OEM supplier of the teletypewriters supplied and sold by most minicomputer manufacturers. Most computer manufacturers OEM peripheral equipment come from manufacturers who specialize in the design and manufacture of computer peripheral equipment.

Off-line - Refers to the use of peripheral device independently of the computer. A teletypewriter may be used off-line to punch a program onto paper-tape.

One's Complement - Refers to the binary value obtained in subtracting the original value from a string of all ones. A computer generates the ones complement by changing 1's to 0's and 0's to 1's.

On-line - Pertains to a peripheral device used under the control of the computer.

Open Shop - A mode of operating a computer system whereby the programmer may exert physical control over the computer. See also entry for closed shop.

Operand - The quantity or data specified in an instruction to be processed.

Operating system - See entry for executive control program.

Operation code - The part of an instruction specifying the operation to be performed.

Output - The data or information (or the process itself) transmitted from the computer to a peripheral device.

Overflow - The condition arising in which the quantity generated exceeds the capacity to store it. In an arithmetic operation it refers to a number generated which is too large to be contained in a register or storage word.

Packed Word - Compressing two or more independent information units for storage in a computer word. For examole, atoring two ASCII characters in a word, or converting several words of decimal digits to a single binary integer.

Page - A segment of memory with a fixed number of storage locations, dictated by the direct addressing range of memory referencing instructions. Generally, all minicomputers have their memories segmented into uniform size pages. Depending upon the manufacturer, the page size will vary from 128 locations to 1024 locations.

Page Zero - Page Zero is the lowest numbered page in a segmented (paged) memory. Usually, instructions in any page may reference page zero. In some minicomputers, page zero may have special addressing characteristics. Also see entry for current page.

Panel - See entry for control page.

Pass - One complete cycle in processing a set of recorded information. Typicall, assemblers and compilers require two or three passes over the source program.

Parity - An error detection technique in which a bit (parity bit) is appended to a byte, character, or word so that the number of bits, in the information unit, is either even (even parity) or odd (odd parity). By this means it is possible to detect errors in transmitting information to and from a computer, its memory or an external device.

Perforator - A paper tape punch is sometimes referred to as a perforator.

Peripheral - Input and output equipment which transmits information to and from the central processor units (including memory) is referred to as peripheral devices, peripheral equipment, or peripherals. Examples would be, magnetic tape reader, high speed paper tape punch, teletypewriter, etc.

POL - Abbreviation for Problem Oriented Language. See entry for Problem Oriented Language.

Port - The electronic facility for connecting the computer to a telephone line through a data set.

Preventive Maintenance - Maintenance performed to detect possible faults before they actually occur. The intention of preventive maintenance is to reduce the likelihood of faults occurring during normal operations of the computer system.

Priority - The automatic regulation of events so that specified activities will be taken over other activities with respect to time.

Process - A sequence of related activities and manipulations on information for a specific purpose.

Processor - Synonymous with central processing unit.

Problem Oriented Language - A programming language designed to conveniently express a class of related problems, e.g. BASIC and FORTRAN and languages for mathematical problems while COBOL is a language for business problems.

Procedure Oriented Language - Synonymous with problem oriented language.

Program - A computer program is a plan for and the construction and arrangement of the necessary statements, instructions and data to achieve the solution to specific problem by the use of a computer. A program will include all the necessary steps and instructions needed to solve a given problem by means of the computer.

Program Library - The collection of available computer programs. Also see entry for Library.

Program Listing - A computer printed record of the instructions in a program. A compiler or assembler will usually produce a copy of the program (program listing) indicating any instructions that are in error.

Programmer - A person who writes or specifies a computer program. A professional person who engages in writing programs.

Programming - The act of creating a computer program.

Pseudo-instruction - A symbolic instruction which has the same general form as a computer instruction, but which is not executed by the computer. The purpose of a pseudo-instruction is to supply information to the assembler or compiler, about the program itself.

Punched Card - A card punched with a pattern of holes to represent information. A punched card can be read by an input device (connected to the computer) called a card-reader. A punched card is commonly called an "IBM card."

Punched Paper Tape - A strip of paper on which information is punched as a pattern of holes. Paper tapes are perforated by a paper tape punch and read by a paper tape reader. Punched paper tape is the most common form of external storage used with minicomputers.

Pushdown List - A list that is constructed and maintained in such a manner that any item retrieved from the top of the list was the last item stored. Pushdown lists are very useful for compilers, interpreters and in the evaluation of arithmetic expressions. Some minicomputers have instructions specifically for the manipulation of pushdown lists, while those that do not achieve the same result using a sequence of instructions. Pushdown lists are sometimes characterized as "last-in, first-out."

Queue - A list constructed and maintained such that the next item to be retrieved is the oldest item in the list. Queues are sometimes characterized as "first-in, first-out."

Radix - Synonymous with base.

Random Access - The ability to access information from a storage device, rapidly and independently of the previous access. Core memory, magnetic drums and disks are examples of random access devices, while magnetic tape and paper tape are examples of sequential access devices.

Reader - Refers input devices such as a card reader or paper tape reader.

Read Only Memory - A storage device whose information can be accessed but not altered. Information is stored in the read only memory by the manufacturer and not changed nor destroyed by a computer program. Micro-programmed computers such as IBM's 360 series, Interdata's 14, Micro system's 810, etc. employ read only memory as part of the computers design. Some minicomputer manufacturers offer a read only memory with the bootstrap program.

Record - A collection of related information units or data items which is treated as a unit. An assembly language instruction, all information pertaining to an inventory item, a line containing a BASIC statement would all be considered a record. A collection of records constitutes a file.

Register - A device within the computer used to store information temporarily and to manipulate the contained information. A computer contains several register interconnected and under the control of the control unit. Registers are used in a variety of computer operations such as arithmetic, logical, and transfer instructions.

Relocatable - Refers to programs which can be placed anywhere in the computer's memory. However, programs which are relocated must have the address references of instructions suitably modified. A relocating loader must be able to make the appropriate address modifications.

Remote Access - Communicating with a computer by means of a terminal located some distance from the computer site. The communication is usually accomplished by means of a telephone line. Time-sharing is the most common example of remote access.

Remote terminal - A device for communicating with a remote access computer facility. A remote terminal must be convenient for humans to use and yet communicate in a manner acceptable to the remote computer. A teletypewriter is a very common example of a remote terminal.

Reset - To restore to an initial state or condition.

ROM - An abbreviation of Read Only Memory.

Rotate - A (right of left) shift of all bits in an accumulator in which bits lost off one end of the accumulator are carried around to enter the vacated bit positions at the other end.

Routine - A sequence of computer instructions which accomplish a limited task. A program may use several routines. Routines which have a common use among several users, may be placed in a library of routines for ready access by other users.

ROS - Read Only Storage - synonymous with read only memory.

Set - To establish a condition or value, e.g. to set a counter to the value one, to set a switch on, etc.

Sequential Access - Refers to a facility or device in which all information must be scanned, up to the desired item, before an access is made.

Shift - A serial motion of bits in a register (right or left). In some types of shifts, bits shifted off the end of a register are lost, while in other types of shifts, bits shifted out of a register end re-enter at the other end.

Sign - A symbol or bit occupying the sign position, indicating an algebraically positive or negative number.

Significant digit - A digit which contributes to the precision of a number. The most significant digit is the left most non-zero digit.

Simulate - By means of a computer program and computer, represent the functioning and behavior of another computer, device, physical, biological or social system.

Software - Compilers, assemblers, supervisory routines, programs, routines and documentation used in the operation of a computer system. The collection of programs as opposed to the computer hardware.

Source language - A program written in symbolic form for input to an assembler or compiler. A source language program will be translated into an object program (in machine language.)

Starting Address - The address of the first instruction of a program stored in the computer's memory. Minicomputers often require programs to be started by entering the programs starting address.

Statement - A meaningful expression or instruction in some symbolic programming language.

Storage - The facility and devices for retaining information, within the computer system, for later retrieval by the computer. Core memory, magnetic drums, disks and tape are all examples of storage devices.

Storage protect - A hardware feature which prevents the inadvertent destruction of stored information. Different types of storage devices have their own kinds of protection mechanism.

Subroutine - A sequence of instructions designed to accomplish a specific task. A subroutine also includes the instructions necessary for other programs to make use of it. Subroutines which are widely used are usually placed in the program library. Subroutine, subprogram, and routine are used synonymously.

Subprogram - See subroutine.

Supervisor - See Executive control program.

Symbol Table - A table of symbolic labels and their corresponding numeric values.

Symbolic Address - An address expressed in terms of symbols, convenient to the programmer, which will be translated into an absolute address by a compiler or assembler.

Symbolic coding - Usually refers to symbolic assembly language coding, in which instructions and addresses are represented symbolically rather than in absolute or numeric language.

Symbolic Editor - A program designed to facilitate the corresponding and updating of other source programs by permitting automatic test editing features. These features might include adding, deleting, searching and inserting of symbolic text.

Syntax - The structure and the rules governing the structure of expressions or sentences in a language. Programming languages have their own definite syntactic rules for construction or analysis of valid sentences.

System - The collection of hardware components, software and programs organized to function as a unit.

Systems house - A company which specializes in the design and integration of computer equipment and software for special purpose applications. Systems houses can often provide devices and interfaces for a given computer which the computer's manufacturer does not offer.

Table - A collection of data items in which each item is uniquely identified by a label or by it's relative position within the table.

Teletype - A trademark of the Teletype corporation for the teletypewriters they manufactur and supply. Teletypes are manufactured in a number of models for various communication applications. The nomenclature most closely associated with the teletypewriters commonly used with minicomputers and time-sharing is as follows:

1 - KSR: Keyboard send receive - refers to the basic teletypewriter which includes a keyboard and printer mechanism.

2 - ASR: Automatic Send Receive - refers to the paper tape reader and punch attached to the keyboard-printer teletype.

3 - Model 33: Standard duty model, i.e. moderate service life, and using the ASCII code.

4 - Model
35: Heavy duty model, i.e. heavy duty use and longer service life, and also uses the ASCII code.

Thus, an ASR Model 33 is a standard duty teletype terminal consisting of a keyboard, printer, paper tape reader and punch. It is the most commonly encountered input-output device for minicomputers and time-sharing. There are additional features which may or may not be required in a particular application.

Teletypewriter - Refers to any typewriter-like device used to communicate electronically with a computer or other similar device. Generic for the teletype or other similar keyboard printer device. "Teletypewriter" is frequently abbreviated to TTY.

Terminal - Any device designed for humans to communicate (two way) with other humans or with a computer.

Time-Sharing - A mode of operating a computer system in which several users obtain interleaved use of the computer system. To each user, it appears as though he is the sole user of the computer.

Translator - A computer program which accepts input, usually in symbolic form, and transforms it to an object form. Assemblers and compilers are examples of translators - they accept a symbolic language program and produce an object language program.

Trap - An unprogrammed conditional branch to a known location. It is automatically initiated by the hardware due to some new condition being sensed by it. The location from where the trap occurred is automatically stored in memory.

Truncate - To terminate a computational process according to some rule.

TTY - A common abbreviation for teletypewriters or for a teletype.

Two's Complement - The radix or base complement in binary notation. A binary numbering convention for positive and negative numbers such that subtraction can be accomplished by the addition of the two's complement. Computers generate the two's complement by adding one to the One's complement (inverting one's and zero's).

User - One who makes use of a computer system.

Utility program - A standard program or routine which accomplishes some basic function in the operation of the computer system. Typical of utility routines are loaders and programs for the reading and writing of peripheral devices.

Variable - A symbolic representation of a quantity which can assume any one of a given set of values.

Word - A set of bits comprising the common unit which the computer manipulates. Minicomputers have word lengths of from 12 to 18 bits. Some computers can also manipulate subword units such as the character, byte and half-word.

Write - To deliver and record information on a storage device or medium such as a magnetic tape.