

PRODUCT SELECTION GUIDE,
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 EDP COMMUNITY OF EQUIPMENT USERS, DESIGNERS AND
 GENERAL MANAGEMENT

Computer Industry Annual 1967-68

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Introducing Computer Industry Annual

During the past year, a variety of business and financial publications have spotlighted the growth of the computer industry. For it has been truly spectacular and it is growing on a world-wide basis faster than any other industry. For example, about 13,000 of the 40,000 computers in use today were just installed during the past year. Sales of computers in most nations of the world are expanding by more than 20% a year. This rate is three times that of the automobile industry which is currently rated second in growth.

Before being recognized as a major new industry, the computer industry was couched without much identity in the broad electronics field. However, this tentative identification for the sprawling computer business soon became outmoded for many reasons. One important reason is due to the emergence of the large volume of non-electronic products and services which have become so intimately associated with computer equipment. Moreover, it is now becoming generally recognized that the so-called conventional electronics industry is no longer a clearly-defined homogeneous market. Instead, the term "electronics" is now considered to be indicative of a **technology** rather than an **industry**. The applications of electronics technology result in many diverse products which are used by many unrelated industries and markets. This is more dramatically evidenced by the diverse applications of digital electronic techniques which now cut across many previously

unrelated fields. And it is digital electronics which forms the underlying technology of the computer industry.

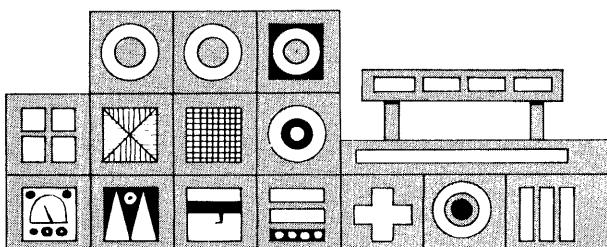
Even with a maximum of rationalization, it would be difficult to consider such items as printers, tape splicers, punched cards, document sorters, tape reels, and software development services as being representative of the traditional electronics industry. The much-publicized "computer revolution," characterizing the present decade, has resulted in the application of computer-oriented equipment by virtually every type of manufacturing firm and commercial enterprise. Thus, machine tool controls, plant monitoring devices, order entry systems, accounting systems, time-sharing systems, communication control systems, and all types of automated equipment are being configured using modern digital techniques. And, many of these techniques are being applied or implemented not only by "electronics" engineers but by people with backgrounds in such diverse fields as mathematics, accounting, hydraulics, meteorology, metallurgy, medicine, insurance, banking, and many others.

Most published reports concerning computer industry growth have dramatized the sales volume of computer mainframes without appropriate mention of the vast array of related products and services. True, computers represent the bulk of the industry's sales. But, peripheral equipment, consumable supplies, communications interfaces, installation accessories, computer test and production tools, equipment leasing, programming services, and a host of other related products and services represent a substantial share of total industry revenues. It is interesting to note that there are less than 25 manufacturers of general-purpose digital computers. Yet, nearly 2000 companies are listed in this first edition of CIA. Also, in addition to general-purpose computers, there are more than 450 other major products specifically itemized in this issue which must be identified with the computer industry.

During the year that it took to plan and produce this first issue, we devoted particular attention to the problem of establishing a format which would be convenient for the reader to use, and easy to update year after year. We believe the broad selection of editorial material, the organization of the directory section, and the overall format best fulfill the diverse needs of our readers.

In each subsequent issue, the Product Directory, Manufacturers' Index, and the Equipment Characteristics Review section will be updated and expanded to reflect the current state of the industry. Because of the accelerated growth of the computer industry, quarterly updating supplements will also be prepared for insertion in the space provided in this issue. The updating supplements will include major new products, industry trends, and techniques, as well as new company listings.

We welcome comments from our readers regarding this first issue, and we invite companies not included in the directory section to submit the necessary corporate data for inclusion in the next issue. Although an undertaking of this magnitude is destined for errors of omission, we believe that the companies and products represented in this issue provide the first comprehensive characterization of the **total** computer industry.



WILLIAM A. GANNON,
Publisher

COMPUTER PRIMER FOR MANAGEMENT

The digital computer is penetrating into nearly every part of the manufacturing and business world, and many managers and executives who were educated, trained, and acquired their business experience in entirely non-technical fields are now faced with decisions in which a computer plays an important or perhaps overwhelming part. For these laymen who are now a part (perhaps unwilling) of the computer business, COMPUTER INDUSTRY ANNUAL presents this introduction to the supposed mysteries of the digital computer. Our aim is to convey a working understanding of the computer, and to define the jargon of the trade in terms of this working understanding, so that communications between the computer-layman and the computer-professional will be enhanced, and so that the executive will have some appreciation of the factors and trade-offs involved in selecting a computer to perform a particular useful function.

Basic Terms

As a first step, the basic terminology associated with the computer should be defined.

■ Computer—"A mechanical or electronic apparatus capable of carrying out repetitious and highly complex mathematical operations at high speeds" (The Random House Dictionary of the English Language, 1966). The key terms are:

"repetitious": The computer cannot perform an endless sequence of operations, cannot innovate, but must go repeatedly through a pre-destined sequence.

"highly complex": depends on the point of view. Frequently, computer operations are completely routine (such as calculation of payroll which

requires a sequence of mundane operations) but the total job done by the computer (calculation of the payroll for a whole company or plant, considering each individual wage rate, deductions, regular time, and overtime, etc.) may be considered "highly complex".

"mathematical operations": could be used to distinguish between a computer and a data processor (see below), but his distinction has largely vanished because most machines of this type are capable of both computing and processing of data.

"at high speeds": computers work at rates varying from thousands of operations per second to hundreds of thousands of operations per second.

■ Data Processor—As stated above, the distinction between a data processor and a computer is no longer of importance, and the terms are commonly used synonymously.

■ Digital—represented by one of a finite number of digits, as opposed to a continuous representation of any value (analog). For example, the ordinary kitchen clock presents a continuous representation of the time of day, while the common outdoor display presents time digitally, to the nearest minute, by means of a finite number of digits.

■ Digital Computer—Performs computations on quantities represented digitally. In contrast, an analog computer performs

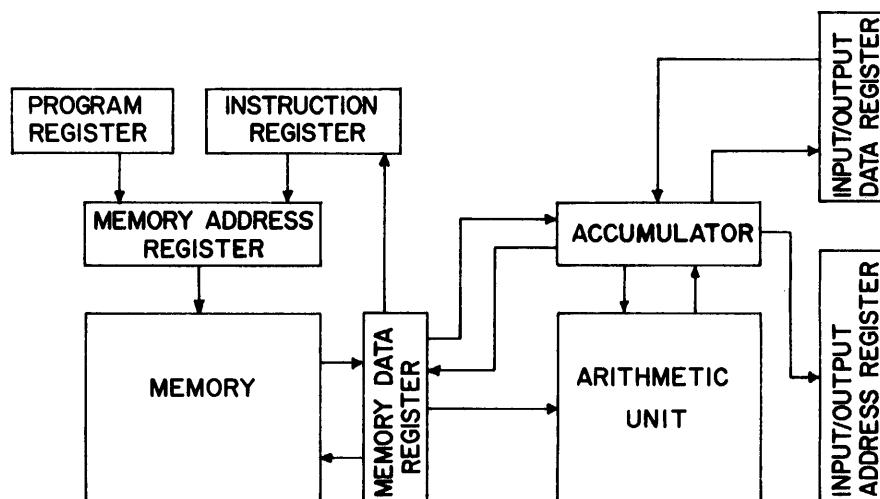


Fig. 1 Basic organization of a stored-program electronic digital computer.

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computations on quantities represented continuously, and a hybrid computer contains both a digital and an analog computation section, each performing the part of an operation to which it is better adapted. A hybrid computer is used, for example, in the process control of a manufacturing operation, where the analog section deals with the continuously-variable measurement and control of the operation, and the digital section performs the computation and decision-making. Digital computers are capable of greater accuracy than analog computers, and are capable of storing data, while the analog computer must operate on the data immediately when it is presented.

- Program—The pre-destined sequence of operations which a computer is constrained to perform.
- Routine—A set of instructions arranged in proper sequence to cause a computer to perform a desired operation. Part of a program.
- Instruction—One operation (add, multiply, etc.) in a program.
- Stored-Program Computer—The computer's program is contained within the computer, and the computer, itself, furnishes the instructions in the sequence in which they are to be performed.
- Scientific Computer—A computer whose organization and design make it most suitable for performing scientific work, and performing many complex computations with high accuracy at a very high speed.
- Business Computer—A computer whose organization and design make it most suitable for performing business accounting work, performing ordinary calculations with normal monetary accuracy, and allowing for a voluminous flow of data into, and out of, the machine.
- Real-Time Computer—A computer whose organization and design are devoted to making it perform its service during the actual time that some external process is taking place, so that the results of the service can be used to affect the external process. "Real-time" is thus relative to the external process: for example, a real-time computer, controlling a steel-making process, may have to supply answers within milliseconds in order to determine adequately the required ingredients and temperature of a batch of steel, but a real-time airlines reservation system may need only react within one minute to keep the airline customer happy.
- Time-Shared Computer—A computer whose organization and design are de-

voted to making it perform as a scientific or business computer for a large number of remotely-located users, by performing each of their operations in turn at a rate sufficiently high that all get adequate service. In general, all users will be performing a different and independent operation.

Organization Of A Stored-Program Electronic Digital Computer

Despite the many possible variations on the organization of a computer, as noted above, there is a basic underlying organizational philosophy which does not change, and it is this basic organization which we shall use to convey a working understanding. (For the purpose of brevity, we shall, from this point on, use the term "computer" to mean "stored-program electronic digital computer", unless otherwise noted.) The basic computer organization is shown in Fig. 1.

The function of a computer is to take data from an external device, perform calculations on it as specified by the stored-program, and supply the results to another external device. In the business world, the data might consist of the number of watt-hours of electricity consumed by an electric company's customers. The device supplying the data would be a punched card reader reading the cards into which this information (data) has been punched; the calculations specified by the program would be to determine the amount of the customer's bill by applying the sliding electrical rate structure to the power consumed; the results would be printed-out in the form of a bill with the customer's name and address on it.

In the scientific world, the data might consist of radar observations of a ballistic missile. The device supplying the data would be the radar set; the calculations would be the solving of complex ballistic equations; and the results would be predictions of the missile's impact point and the time of impact which would be flashed on a display screen at NORAD headquarters.

With this kind of sequence of events in mind, we can examine the components of a computer as represented in Fig. 1.

- Memory—The memory serves to store the program which is to be executed, store the input data until it is needed for processing, store intermediate results during the computation, and store final results until they are ready for output. The memory is a principal element of the computer, and the cost and speed of the computer are largely governed by the cost and speed of the memory. The memory stores its contents in the form of words: a word generally consists of from one to six characters or digits, depending on the computer, and a computer memory may be capable of storing from one thousand words to several hundred thousands of words.

- Memory Address Register—A word is stored-away in the memory, or retrieved from the memory, by designating the location of a particular memory word-position in the memory, and giving the com-

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mand to "store" or "fetch". The memory address register is used to designate this address. There will be as many unique addresses (locations) in the memory as the number of words which the memory is capable of storing. The store or fetch command is given by the Control Unit, an all-pervading logical complex which determines what operation is performed at what time. The control unit is not illustrated in Fig. 1; it can be visualized as the "big brother" which causes the elements shown in Fig. 1 to perform the operations described in this text.

■ **Memory Data Register**—When storing a data word into memory, the data word is placed into the memory data register, the address at which it is to be stored is placed into the memory address register, and the store command causes the data word to be stored at the desired address. When fetching a data word, the address of the word is placed into the memory address register, and the fetch command causes the word to be transferred from the specified address to the memory data register.

■ **Program Register**—The program consists of a sequence of instructions which the computer is to perform, and the program is stored in the memory in the proper sequence; that is, the first instruction is stored in location 001, the second is stored in 002, etc. The program register keeps track of the location from which the next instruction is to be fetched, by counting the instructions as they are performed. For example, if the fifth instruction, which was located in memory position 005, is being performed, the program register has counted to 006, the address of the next instruction. When the time comes to fetch the next instruction from memory to determine what operation it specifies, the program register will transfer 006 into the memory address register.

■ **Instruction Register**—It is extremely important to recognize that the memory contains both instructions to be performed (the program) and the data on which the instructions are to be performed, and that these two kinds of stored words are treated in two entirely separate ways. The address of an instruction is specified by the program register; when fetched into the memory data register, the instruction is transferred to the instruction register, where it is examined by the control unit to determine:

What operation (add, multiply, etc.) is required?

Where is the addend (or multiplicand, etc.) located?

Where is the augend (or multiplier, etc.) located?

Where should the result be placed?

If, as is usually the case, one of the operands is to be obtained from the memory, the appropriate address, contained in the

instruction, is furnished to the memory address register by the instruction register.

■ **Accumulator**—As the instruction register is taxed with the handling of all instruction words as they are retrieved from memory, the accumulator serves an equally important function for the data words. In general, the accumulator contains one of the operands for any arithmetic operation, the other operand being in memory, and the result of an arithmetic operation is usually placed into the accumulator. Data words can be fetched from memory to the accumulator, or stored from the accumulator into the memory.

■ **Arithmetic Unit**—Performs the specified arithmetic operation between a word contained in the accumulator and a word fetched from memory into the memory data register. (This describes a single-address computer; more complex computers can carry out arithmetic operations between two words in memory.)

■ **Input/Output Data Register**—Data coming from an external device is placed into this register by the device, and subsequently transferred into the accumulator for use inside the computer. Data going to an external device is transferred from the accumulator to the input/output data register, from which it is removed by the device. The input/output data register serves the purpose of temporary storage and speed-matching; direct communication between the accumulator and the external device is inconvenient because the two are seldom ready at the same instant, and time would be wasted by one waiting for the other. In general, the computer will be much faster than the external device. The input/output data register serves somewhat like an RFD mailbox, with which we can send or receive a letter without standing and waiting for the postman to come by.

■ **Input/Output Address Register**—Several external devices are usually connected to the computer, and the input/output address register designates the one device which is to send or receive data to or from the input/output data register at any time.

Computer Program And Instructions

Before discussing the computer program and the instructions which comprise it, some additional definitions of terms are in order.

■ **Instruction Repertoire**—A computer is capable of performing only those operations which have been built into it. These operations are defined by the instruction repertoire which is a list of the instructions which can be used to make up a program for the computer.

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■ Instruction – We have defined an instruction as one step in a program, but need now to amplify further the makeup and function of an instruction. It consists of three basic parts (we are limiting discussion to only single-address computers):

Operation Code ("Op Code"): The portion of an instruction which tells what operation is to be performed (add, transfer to input/output data register, store into memory, etc.)

Modifier: An appendage to the code which further amplifies it, or modifies the operation. For example, if the result of an "add" operation is normally placed into the accumulator, the modifier may be used to alter the operation so that the result is placed into memory.

Address: The memory location which contains the word that will enter in the operation specified by the Op Code. (This will become clearer as we examine some specific instructions.)

It is important to realize that instructions (and, for that matter, most data as well) for a computer are absolutely content-position-sensitive: for example, if we have a seven-character instruction, the first three will always comprise the Op Code, the fourth will always be the modifier, and the last three will always be the address. Any other order will make no sense to the computer.

■ Peripheral Equipment – That which is referred to above as an "external devices." Also referred to as I/O Devices.

To illustrate the workings of a computer and its program, we shall postulate an instruction repertoire for the simple computer configuration shown in Fig. 1. This instruction repertoire will, by the definition of the instructions, define the operation of the control unit and the arithmetic unit. Since the control unit causes the next instruction in the program to

be executed immediately upon completion of the current instruction, the operation of the program register and instruction register are implicit in the computer, and for programming purposes we can ignore them. We shall, therefore, work with the modified computer organization of Fig. 2, which shows only the parts of the computer which are of interest to the programmer. Note that there are several other changes from Fig. 1 to Fig. 2.

For brevity, the accumulator, arithmetic unit, memory address register, memory data register, input/output data register, and input/output address register have been designated, in the text that follows, by the abbreviations ACC, A.U., MAR, MDR, I/O-D, and I/O-A, respectively.

The two units of peripheral equipment necessary to perform the electric-company billing problem, described, above have been added to Fig. 2 and designated "I/O1" and "I/O2". A unit designated I/OR (I/O Ready) has been added. I/OR is the means by which the I/O device can inform the computer that it is ready, or it has placed a word into I/O-D, or it has taken a word from I/O-D or some other message, the meaning of which is well known to the computer at the time it occurs. I/OR is merely a latch, or signal, like the nod of one's head: the interpretation of it is up to the computer.

For our simple instruction repertoire, we shall ignore the modifier character, and work with simple six-character instructions. All instructions will have the format in which the first three characters are the Op Code, and the last three characters will be the associated address, if needed (and will, therefore, be numbers). We shall specify that the memory contains one thousand locations, with addresses designated 000 through 999. First we shall cover the needed arithmetic instructions:

ADDXXX: add the contents of memory location XXX to the contents of ACC, and place the result in ACC; symbolically:
 $ACC + XXX \rightarrow ACC$

SUBXXX: subtract the contents of memory location XXX from the contents of ACC, and place the result in ACC; symbolically:
 $ACC - XXX \rightarrow ACC$.

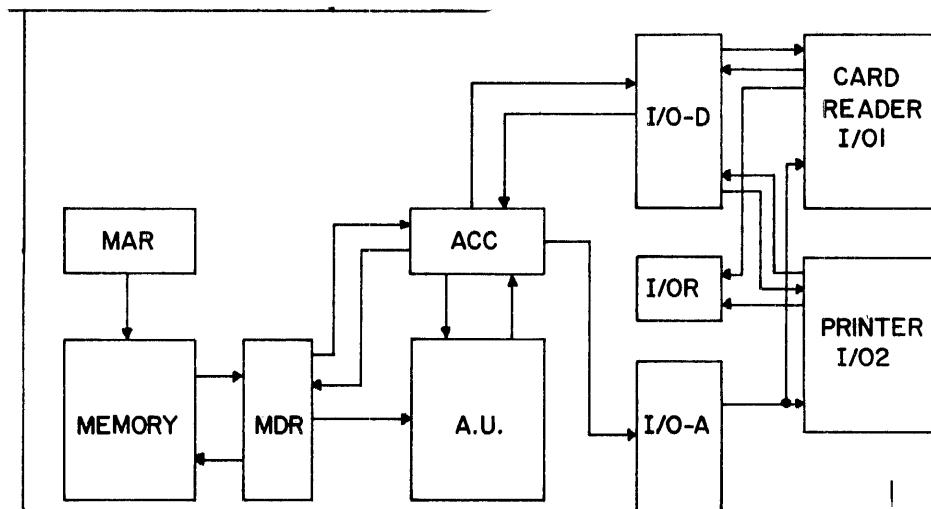


Fig. 2 Computer organization for illustrating instruction repertoire.

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MLTXXX: multiply the contents of XXX by the contents of ACC, and place the result in ACC: (ACC) (XXX) → ACC.

Next we shall cover the instructions used for data transfer and manipulation:

LODXXX: fetch the contents of XXX to ACC: XXX → ACC.

STOXXX: store the contents of ACC in XXX: ACC → XXX.

TCA: transfer the contents of ACC to I/O-A: ACC → I/O-A.

TCD: transfer the contents of ACC to I/O-D: ACC → I/O-D.

TDC: transfer the contents of I/O-D to ACC when I/O-D is set: I/O-D ACC when I/O-D is set.

(Note that LODXXX and STOXXX involve the use of MAR and MDR, but they are not mentioned in the instruction since they are implicit operators in the function of storing and fetching into or from memory.)

LOCATION #	
CONSTANTS:	21 WORDS
SCRATCHPAD:	80 WORDS
INPUT:	200 WORDS
OUTPUT:	200 WORDS
PROGRAM:	499 WORDS
	- 000
	- 020
	- 100
	- 300
	- 500
	- 999

Fig. 3 Memory map for electric billing program.

The last three instructions are used in the program to make decisions. The simple statement that a program proceeds through a fixed sequence of instructions is not strictly true, in that the program is able to make the decision to transfer to another part of itself rather than execute the next sequential instruction, on the basis of results obtained while performing computation. The instructions used to perform this kind of operation are

called transfer or jump or branch instructions; their use will be made more clear in the example below. In our instruction repertoire, the jump instructions are

JIOXXX: take the next instruction from location XXX if I/OR is set. If I/OR is not set, take the next sequential instruction.

JCNXXX: take the next instruction from location XXX if ACC is zero or negative. If ACC is positive, take the next sequential instruction.

JJJXXX: take the next instruction from XXX.

Since the instructions, as well as the data, are stored in the memory, these instructions address memory in the same sense as do the data instructions. Returning for a moment to Fig. 2, we can see that if the conditions specified by a jump

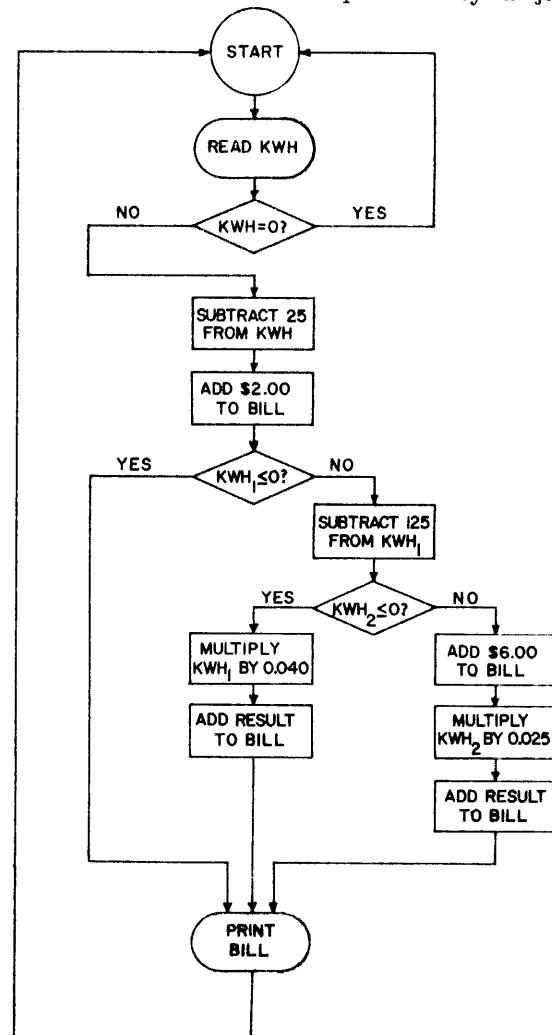


Fig. 4 Program flow chart for electric billing problem.

instruction are satisfied, the address of the next instruction is inserted into MAR from the instruction register (where the whole jump instruction is stored while being executed), instead of from the program register. XXX is also inserted into the program register when a transfer is executed, since the sequential selection of instructions will proceed from XXX, not the location of the transfer instruction.

We have therefore specified a computer with

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eleven instructions and 1000 words of memory to perform the task at hand: this is the hardware with which the programmer must work. The programmer must allocate the memory locations to particular tasks, and write a program using these instructions. To complete the creation of a computer + program system, which will perform the desired function, we shall use the electric-company billing operation to illustrate the process.

Example: Programming The Electric Company Billing Calculation

One of the programmer's tasks is to allocate the available memory locations to the various functions for which the memory must be used. In this problem, these are:

- Storage of constants needed.
- Storage of the program.
- Storage of the input data.
- Storage of intermediate results (a "scratchpad" area.)
- Storage of output data.

Fig. 3 shows a reasonable memory allocation for this problem; such a diagram is called a memory map.

The creating of a program consists fundamentally of three steps.

1. Specification of what operations will be performed and the sequence in which they will be performed. This specification takes the form of a program flow chart which defines the general logic of the program.
2. Specification of the individual elements (routines) of the program: this is the same process as above, but in more detail and for each area of the program. This specification takes the form of a detailed flow chart for each routine.
3. Writing the instructions: If the flow charts are properly done, the instruction sequence for each routine can be created easily and directly from the detailed flow chart, and the individual routines can be joined to form the program using the program flow chart.

For our electric company billing problem, the program flow chart is shown in Fig. 4. The program basically performs three routines:

1. Read the portion of a card which contains the number of kilowatt-hours used by the customer during the past two months. For the sake of simplicity, we will assume that the remaining information on the card—customer name and address, customer identifying number, etc.—is transferred directly from the card reader to the printer which is printing the invoice, therefore the computer is required only to take the kilowatt-hours (KWH) used, compute the amount due, and provide it to the printer.

2. Compute the amount due using the following schedule of rates:

2.00 dollars for the first 25 KWH.
4.01 cents/KWH for the next 125 KWH.
2.50 cents/KWH for the remainder.

3. Print the amount due, and go on to the next card.

The detailed flow chart for the first routine, "read KWH", is shown in Fig. 5. It comprises the following steps.

1. The command, which will cause the card reader to read a card, has been previously stored in the "constant" area of memory. It is extracted and placed into ACC, and is then:
2. Transferred into I/O-A; the card reader continuously monitors the contents of I/O-A, and therefore will react to the command after it has been placed therein.
3. The computer waits for I/O-D to be set by the card reader, indicating that the card reader has placed the desired word from the card into I/O-D.
4. The word in I/O-D is placed into the accumulator, and from there:
5. into the first location of the input area of memory.

Once the detailed flow chart exists, the creation of a sequence of instructions to perform the routine is straightforward.

We have specified that the computer contains 1000 words of memory. We shall now further specify that each word consists of four characters. This allows us to store one instruction per word in the memory: the Op Code will be stored in the first character of memory (suitably coded so that, for example, a first-character "A" is interpreted as "add", an "S" as "subtract", etc.) and the address (which will be three digits) in the following three characters. ACC, MDR, and I/O-D will also be one word in capacity, so that full memory words may be operated upon and manipulated.

The list of instructions to implement the detailed flow chart consists of both the instructions and their assigned locations in memory, since the program, as well as the data, is stored in the memory. In the instruction sequence below, the memory address where each instruction is stored is shown in the left column, the instruction sequence is listed in the center column, and the right column shows the contents of ACC after the instruction on that line has been executed; this makes following the program sequence easier.

Address	Op Code & Address	ACC Content
500	LOD	000 "read-a-card"
501	TCA	NNN
502	TDC	NNN word from card reader

We have chosen to store the command which will be interpreted by the card reader as "read-a-card"

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in the first location of the constant area (000). Therefore, the first two instructions retrieve that constant to ACC and transfer it to I/O-A. (The "NNN" in the address portion of an instruction

Address	Op Code & Address	ACC Content	
503	JCN	500	KWH
504	SUB	002	KWH-25
505	JCN	513	KWH-25
506	STO	020	KWH-25
507	SUB	003	KWH-25-125
508	JCN	515	KWH-25-125
509	MLT	005	(KWH-25-125) (0.025)
510	ADD	001	(KWH-150) (0.025) + 2.00
511	ADD	006	(KWH-150) (0.025) + 8.00
512	JJJ	518	(KWH-150) (0.025) + 8.00
513	LOD	001	2.00
514	JJJ	518	2.00
515	LOD	020	KWH-25
516	MLT	004	(KWH-25) (0.040)
517	ADD	001	(KWH-25) (0.040) + 2.00

indicates that no address is associated with that instruction—because it does not deal with memory—and filler or dummy characters occupy those character positions in memory.) The third instruction accepts the word from I/O-D when the card reader has placed it there and set I/OR; we end the input (the number of KWH used) in ACC.

We have, therefore, created the program for the first part of the program flow chart, which is represented by the detailed flow chart of Fig. 5. Fig. 6 shows the detailed flow chart for the arithmetic portion of the program; the listing of instructions is below. Note in Fig. 7 that we have assigned the necessary constants to be stored in specific locations of the constant area.

From the electric rate schedule, we see that the billing operation will fall into one of four categories:

1. No KWH used: therefore no bill. The test in step 503 will if ACC less than or equal to 0, transfer the program back to location 500, which will cause the next card to be read, thus giving no billing output for this card.

2. Less than 25 KWH used: the minimum bill of \$2.00 will be created. Step 503 will show ACC less than equal to 0, therefore the program will go to step 504, subtract 25 from the input KWH, and test in step 505 to see if ACC less than or equal to 0. If there were 25 KWH or less, ACC will be less than or equal to zero, and JCN 513 will transfer the program to location 513 where the required \$2.00 is loaded into ACC. Step 514 then transfers the program to location 518, where the "output" routine will start.

3. Between 26 and 150 KWH used: the bill is \$2.00 plus \$0.040 times the KWH over 25. Step 505 will show that ACC is still positive after 25 has been subtracted from KWH; step 506 stores the number into the scratchpad, location 020, for further use if needed. Step 507 subtracts 125 from KWH-25, and step 508 discovers that this resulted in a negative number (or zero), therefore the original number of KWH was 150 or less. The program is, therefore,

transferred to step 515, where the number of KWH in excess of 25 is retrieved from the scratchpad, multiplied by \$0.040 in step 516, and \$2.00 added to the result in step 517. The correct result is now ready for output in step 518.

4. Over 150 KWH used: the bill is \$2.00 for the first 25 KWH, plus \$6.00 for the next 125 KWH, plus \$0.025 for each KWH over 150. The tests in steps 503, 505, and 508 all find ACC less than or equal to 0, and at the end of step 508, ACC contains the number of KWH over 150. This is multiplied by \$0.025 in step 509, \$2.00 added in step 510, \$6.00 added in step 511, and the program transferred to the output routine by step 512.

The output routine is shown in detailed flow diagram form in Fig. 8, and the program is listed below.

Address	Op Code & Address	ACC Content	
518	TCD	NNN	Bill
519	LOD	007	"print" command
520	TCA	NNN	
522	JIO	500	
523	JJJ	522	

At the end of the arithmetic routine, in all cases, the amount of the bill is in ACC. This is transferred into I/O-D, from which the printer will obtain it for printing, in step 518. The "print" command is then obtained from the constant storage in step 518, and transferred to I/O-A in step 519. The printer will recognize this command, procure the output data from I/O-D, and set I/OR to signify it has accomplished this mission. Until this is accomplished, the program will shuttle ("loop") between steps 522 and 523; step 522 transfers the program back to start (read-a-new-card) after I/OR has been set, but until I/OR is set, step 522 leads to step 523, which transfers the program back to step 522.

Comments and Further Definitions

Once the basic operations are understood by means of the simple example above, the following explanatory notes will serve to relate the example to the real-life operations of the normal computer process.

■ Bulk Input-Output—although an input and an output area were assigned in the memory in the above example (and referred to in the flow chart), no use was made of them. In a normal operation, a large amount of input data (instead of the one word used above) would be brought into the computer, initially (one word-at-a-time), and stored in the input area. One-word-at-a-time would then be taken from the input area, processed, and the results stored in the output area. At the end of the process, then, a group of input words would have been processed, creating a group of output words, and this entire group would then be transferred (a word-at-a-time) to the output device.

■ Arithmetic Operations—we have sim-

plified the A.U. in the above example, to a "black box" which magically takes in two numbers and performs a specified operation on them. The design of an A.U.

i.e., instructions can be altered in the course of executing the program. An example would be the loading of a number of input data words into the input area starting

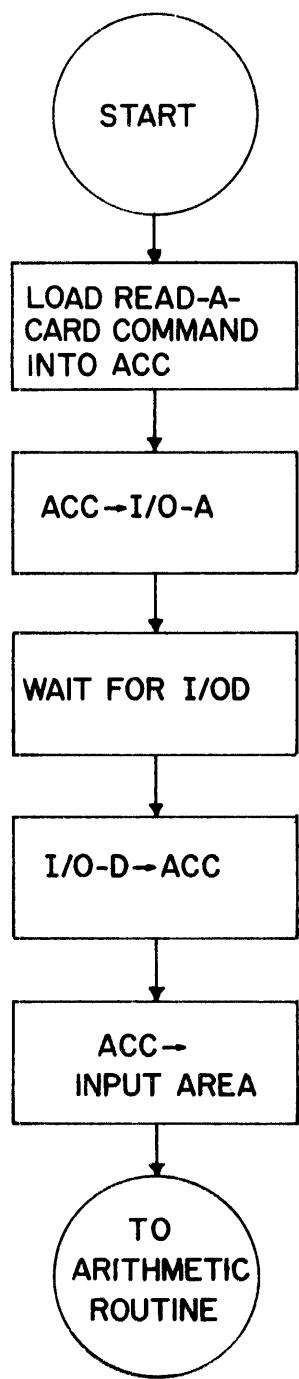


Fig. 5 "Read KWH" routine; detailed flow chart.

is an all-pervading consideration, involving the machine code, provision of instructions for decimal point and sign manipulation, etc.

■ Program Modification—Since the program is stored in the memory in the same way as the data which is being operated upon, the program can be made dynamic,

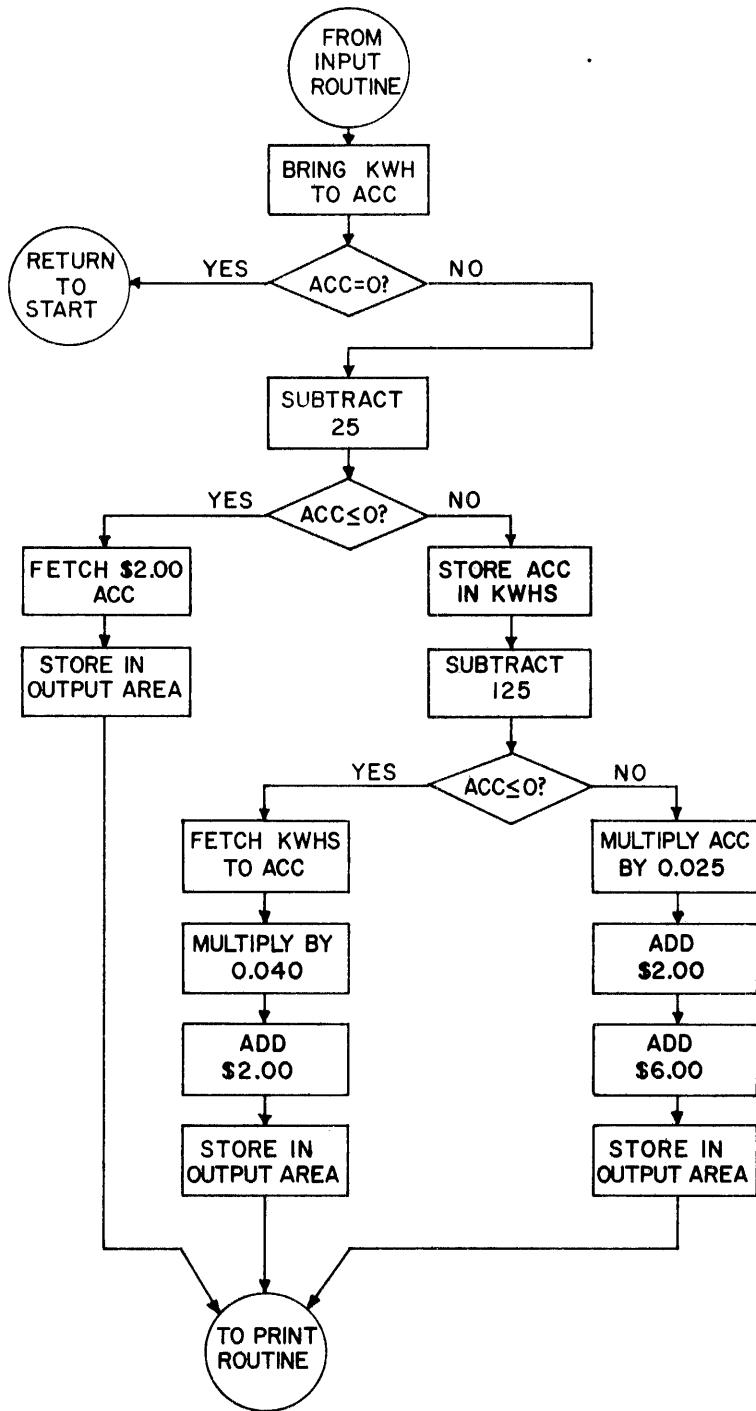


Fig. 6 Arithmetic routine; detailed flow chart.

at location 101. The first word would be put away by an STD 101 instruction; the constant 1 would then be added to 101, and the resulting 102 would replace the 101 in the STO instruction. This incrementing would continue until all the data was stored.

Based on the knowledge of the above example, we can impart a working "feel"

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for more sophisticated computer concepts through the use of a glossary.

- Algorithm—A procedure for solving a particular problem: e.g., the detailed flow chart for the arithmetic routine, above. An algorithm provides a basis from which a routine can be written.

- Assembler—A program which assists the programmer by translating human-understandable notation to machine-understandable codes and assists him in keeping track of memory assignments. For example, the assembler would perform two operations in the above simple example.

1. Translate the Op Codes, ADD, SUB, etc., to a code which would be recognized by the control unit.

CONSTANTS	000 "READ-A-CARD"
001	2.00
002	25
003	125
004	.040
005	.025
006	6.00
007	"PRINT"
SCRATCHPAD	020 KWHS
INPUT	100
OUTPUT	300
PROGRAM	500 } 501 } 523 }
	PROGRAM STEPS: SEE TEXT
	999

Fig. 7 Memory assignments for electric billing program.

2. Allow the use of symbolic addresses while programming. For example, we might designate the address of the beginning of the output routine by the term "out", and write instructions 512 and 514 as TTT "out", without bothering to determine, at that time, the exact location where "out" will be lo-

cated when the address of the output routine was located, and equivalence between address 518 and "out" would be specified, and the assembler would go back through the program and insert address 518 for each occurrence of "out".

- Compiler—A program which assists the programmer by allowing him to write the program in a completely human-oriented language, which is not associated with any particular computer. The compiler translates the program written in compiler

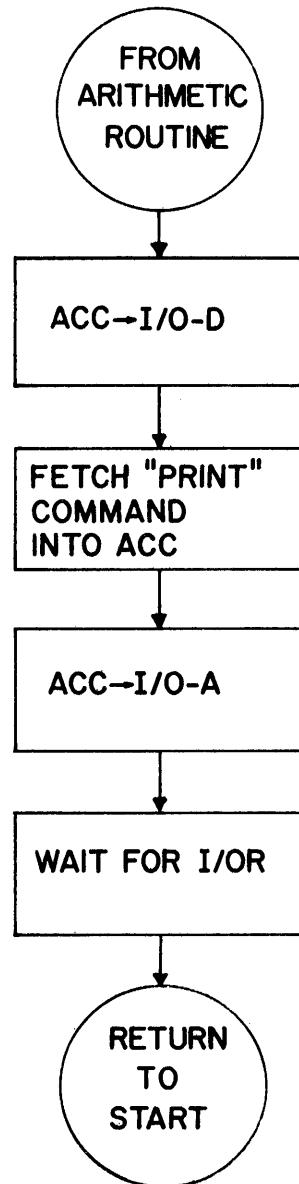


Fig. 8 Output routine;
detailed flow chart.

language to a sequence of instructions which will cause a certain computer to perform the program. The compiler handles memory allocation and generates machine instructions and machine code; many machine instructions may be generated to execute one compiler instruction, e.g., the compiler command "multiply" may result in a long string of "add" and "shift" instructions

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in the machine. Some examples of compiler languages:

- ALGOL—algorithmic-oriented language.
- COBOL—common business-oriented language.
- FORTRAN—formula translating system.

■ **Diagnostic Program**—A program whose sole function is to “exercise” all parts of the computer, and which is so organized that a malfunction will create clues to its own location and the clues will be printed out by the diagnostic program.

■ **Interrupt**—The process of stopping a program being executed, performing a high-priority routine, and then resuming the original program with a loss of nothing but time. An interruptable computer completes the instruction currently being performed, stores away the contents of all registers (ACC, program register, etc.), then jumps to a stored interrupt-service program. After servicing the interrupt, all registers are restored to their original state and the program proceeds.

■ **Multiprocessing**—The simultaneous execution of two or more programs.

■ **Multi-programming**—The interleaved simultaneous execution of two or more programs; constitutes multi-processing.

■ **Parallel Processing**—The simultaneous execution of two or more programs by a computer having two or more arithmetic units; constitutes multiprocessing.

■ **Software**—The collection of programs and manuals associated with a computer.

■ **Direct Address**—The address portion of an instruction which specifies the location of an operand.

■ **Indirect Address**—The address portion of an instruction which specifies a location in memory which contains the actual address of an operand. Useful in program modification. An instruction is specified as indirect by the coding of the Op Code modifier.

■ **Indexing**—The address of the operand is obtained by adding the address portion of the instruction to the contents of an index register. Also useful in program modification, and also specified by the modifier. For example, a number of input data words can be loaded into an input area by specifying the starting address of the input area as the address portion of an STD instruction, and counting the number of words already stored in the index register. The sum of the starting address and the index register will always give the desired storage address.

■ **Effective Address**—The end address that

is selected for action, after the direct address and all indirect addressing and indexing have been applied.

■ **Relative Address**—An address specified as being a certain distance relative to another known address. For example, if indexing is being employed, the index register specifies the effective address relative to the basic starting, or direct, address. The relative address specifies the distance from the effective address (the absolute address) to a base address.

■ **No-Op**—A dummy instruction which accomplishes nothing except to consume time.

■ **Fixed Word Length**—The number of characters in a computer word is specified and fixed. For example, in the computer specified in our example, a four-character word was specified, and all operations must proceed in units of four characters or numerals.

■ **Variable Word Length**—The number of characters in a computer word is variable, and markers are supplied to designate the boundary of a word. Although we have defined the word as being the number of characters stored in a memory location (a computer word), the variable word-length concept refers to the way in which the arithmetic operations and other manipulations proceed. In our fixed word-length computer, an ADD instruction causes one four-digit word to be extracted from memory, added to ACC, and the answer presented in ACC. In a variable word-length version, the computer words in memory are considered to be attached end-to-end, and an ADD instruction would cause as many words to be extracted and added as was necessary to get to an end-of-word boundary marker.

■ **Multiple Precision**—Similar in concept to variable word length; a word may consist of two or more (but some fixed number) computer words.

■ **Fixed Point**—Numbers inside the computer are represented as digits with the decimal point at a known location, e.g., 96.84.

■ **Floating Point**—Numbers inside the computer are represented as significant digits times a power of ten, and the decimal point may be manipulated by manipulating the power of ten. e.g., .9684 x 10².

■ **Binary**—A number system in which the base or radix is 2, and the possible digits are 0 and 1. Used in computers because the component parts (transistors, circuits) are relatively easy to create and cheap to produce if they are required only to represent the two digits 0 and 1.

■ **Bit**—A binary digit.

- Decimal—A number system in which the base or radix is 10, and the possible digits are 0,1,2 . . . 8,9. In common use by humans.
- BCD (Binary-Coded-Decimal)—A decimal notation in which each decimal digit is represented by four bits. Used as the internal code of a “decimal” (business-oriented) computer.
- Octal—A number system in which the base or radix is 8, and the possible digits are 0,1,2 . . . 6,7. A useful representation of binary since three bits comprise one octal digit.
- ASCII (American Standard Code for Information Interchange)—A convention of representing the alphabet, the ten decimal digits, and a variety of other information with a seven-bit code. Approved by the United States of America Standards Institute, and intended to provide a common coding method so as to enhance information interchange between computers.
- I/O Typewriter—An input-output device which operates as a normal typewriter with the additional feature that information typed from the keyboard is electrically entered into the computer, and the computer is able to send electrical information to the typewriter to be automatically printed.
- Printer—An output device to which a computer can send information to be printed. May have from 4-200 columns of type, operate at 1-15 lines per second.
- EAM Equipment (Electrical Accounting Machine)—Electromechanical data processing equipment; not a computer.
- OCR (Optical Character Reader)—An input device which reads printed material and converts it into digital electrical signals which can be processed by the computer.
- Direct Memory Access (DMA)—A feature which allows an I/O device to put data directly into, or take data directly from, the memory by allowing the device to have limited access to MAR and MDR.

Peripheral Equipment And More Definitions

- Central Processor—The part of a computer which interprets and executes instructions; includes the memory and A.U.
- Magnetic Tape Handler—An input-output device used for storage of information on a thin, magnetically-coated tape, usually $\frac{1}{2}'' \times 2400'$, wound on reels which can be removed from the equipment and stored.
- Magnetic Drum—An input/output device which stores information on a magnetically-coated drum, rotating at high speed.
- Magnetic Disk File—An input/output device which stores information on one or a number of magnetically-coated disks, rotating at medium or high speeds.
- Random Access Time—The time required to fetch or store information from, or into, an arbitrary (random) location in a storage device.
- Magnetic Core Memory—A storage device which stores each bit in a small individual magnetic element. Used primarily for central processor memory.
- Punched Card Equipment—Input-output devices used to read or punch information from, or onto, a $3\frac{1}{4}'' \times 7\frac{3}{8}''$ card, commonly-known as an “IBM card”.
- Perforated (or Punched or Paper) Tape Equipment—Input/output devices used to read or punch information from, or onto, 1” wide “paper” tape.

How To Read A Computer Specification

It is not intended that this discussion will enable the layman to evaluate one computer versus another, since this can be done only in terms of the job which the computer is required to do; however, we shall briefly relate the features commonly advertised or specified in computer sales literature to the concepts introduced above; this will enable the reader to evaluate a given computer in terms of this simple discussion.

- Word Size—The number of bits in a memory location. In this article we have discussed word size in terms of the number of characters; to relate this to the number of bits, we note that (roughly) a character can be represented by each 6 bits. In binary-arithmetic computers, the concept of a character is not appropriate, and the number of quantities which can be represented in a word is exponentially proportional to the number of bits in the word.
- Memory Size—Two numbers are usually specified: The minimum configuration and the maximum allowable. The minimum is the number of words (locations) which the computer memory will provide at the quoted basic price. The maximum is the number of words to which the memory can be expanded, at additional cost.
- Memory Cycle Time—The time required to fetch a word from memory into MAR, then write it back into the memory so that it is present both in MDR and in the original location. (The nature of the “read” process in a core memory destroys the information while reading it.) The

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speed capability of the computer, that is, they indicate the maximum rate at which bits can be fetched from, or stored into, the memory.

■ Add Time—The time required to extract an "ADD" instruction from the program memory, interpret it, add the two specified numbers, and place the result in ACC. Indicative of the speed capability of the computer since it takes into account fetches from the memory, structure of the instructions, and speed of the A.U. If normalized to a particular problem (e.g., speed of adding two 5-digit numbers), add time can be very informative as to relative speeds between computers. Similar comments apply to Fetch or Store Time, and Multiply Time figures.

■ Index Registers—if available, they will increase computer speed by reducing the number of instructions required to perform most programs. Also true of Indirect Addressing.

■ Number of I/O Channels—Indicative of the ease with which I/O operations can be accomplished with the I/O devices required. If the channels are buffered, then

the programming and computer times required to handle these I/O devices are reduced. There is normally a minimum and maximum number of channels available.

■ Interrupt Structure—The number of interrupts (the number of devices which can be made to interrupt the program) and their hierarchy (does one take precedence over another, can an interrupt interrupt an interrupt?) is indicative of the power of the system in a real-time application, or with many I/O devices connected. Interrupt features may be optional.

■ Compiler—What compiler program is provided for use with the system? This must be evaluated relative to the kind of application.

Summary

It is hoped that this primer provides sufficient surface understanding so that the manager/executive can appreciate the capabilities of computers and the skills of computer personnel. Although a simplified computer organization was used for illustration, this basic understanding should be of great value in computer-related management decisions.

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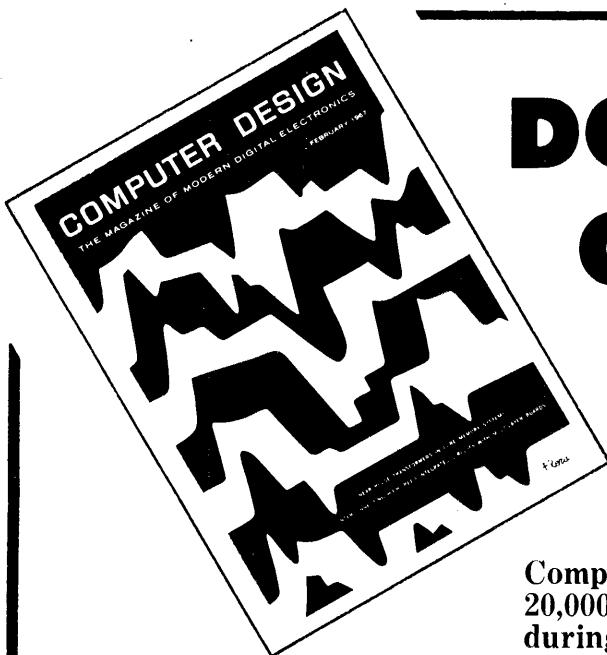
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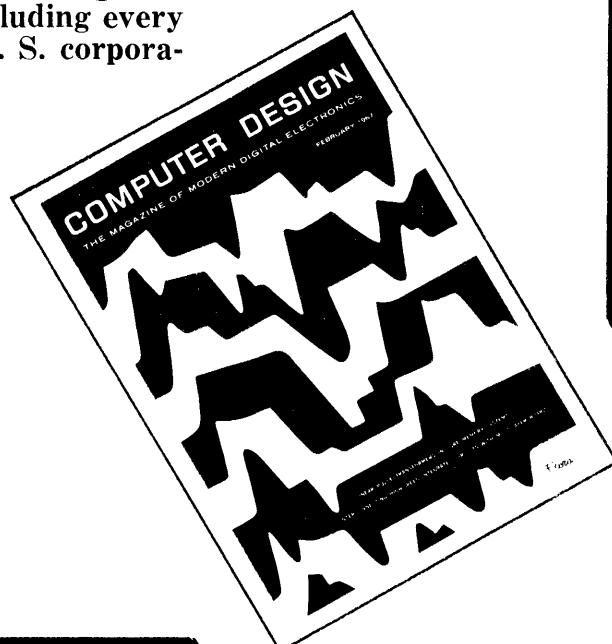
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COMPUTER MANUFACTURERS' PROFILE

STATE OF THE INDUSTRY

Computer sales in 1966 soared to an all-time high of \$4.2 billion while the year-end order backlog reached a record level of \$6 billion. About one third of the computers now in use were installed during 1966. The booming computer industry now ranks first in growth with an annual rate of about 20% which is three times faster than the second ranked automobile industry. During the last quarter of 1966 and early part of 1967, computer stocks were consistently among the high flyers. In the first quarter of 1967, the stocks of Burroughs, Control Data, Digital Equipment Corporation, Scientific Data Systems, and Systems Engineering Laboratories more than doubled their 1966 lows.

Major new product announcements were scarce in 1966 among the larger EDP manufacturers. The few exceptions were the UNIVAC 9000 series computers, and the Burroughs B2500, B3500, and B6500 machines. During 1966, major attention was devoted to stepped-up production of third generation machines and further development of the associated software packages. The early production problems encountered by IBM with System/360 apparently were overcome since year-end production of System/360's reached the anticipated peak of 1,000 systems a month. Chairman Thomas J. Watson, Jr., in the 1966 Annual Letter to Stockholders, stated that "the highest priority will continue to be placed on programming systems development to improve the usefulness of System/360 to our customers." First deliveries of the large-scale System/360 Models 67 and 75 began in the first half of 1966. However, IBM reported delays in delivery of certain programming packages associated with the 360's time-sharing and large-scale scientific applications, and recently decided to withdraw certain programming systems support for time-sharing.

Honeywell EDP Division reported 1966 sales of \$182 million which moved them to the coveted second place for the year. Based on accumulative sales to date, however, Honeywell is in third place with Univac second and Control Data fourth. After turning the corner in late 1965, Univac maintained profitable operations during 1966 even in view of the high development costs normally associated with new computer systems such as the Univac 9000 series.

Control Data Corporation moved back into the black in the first half of the fiscal year ended December 31, 1966 after a net loss of \$1.9 million in the year ended June 30, 1966.

Small Companies Gain Momentum

Among the smaller manufacturers of computers, several new products were announced during 1966 and most small firms moved further into the black. Scientific Data Systems (SDS), referred to as "the largest of the small computer companies," announced the Sigma family of computers and the first three members in the new family, the 2, 5, and 7, were introduced. Another milestone in the relatively short history of SDS occurred in mid-1966 when trading of SDS stock on the New York Stock Exchange began.

Digital Equipment Corporation, a major supplier of small-scale scientific computers, was approved for listing on the American Stock Exchange in November, 1966. The initial public offering, handled by the underwriting firm of Lehman Brothers, included 375,000 shares of DEC stock. During the last quarter of the fiscal year ended September 13, 1966, the PDP-9 and the first "under \$10,000 computer," the PDP-8/s, were announced by DEC. Hot on the heels of these announcements came the medium-size PDP-10 which DEC introduced in November 1966.

Systems Engineering Laboratories, Inc. (SEL), located in Fort Lauderdale, made important gains in 1966 with sales of the company's new 800 series of integrated circuit computers. After incurring a net loss of \$403,053 in the fiscal year ended June 20, 1966, SEL climbed back into the black with a net income of \$82,200 on sales of \$2,745,215 for the first half of the fiscal year ended December 9, 1966. The losses for fiscal 1966 were attributed to the unanticipated high costs incurred in the development of the SEL-810 and SEL-840 computers. SEL's first public offering (over the counter) of stock began in March, 1966 which was headed by the New York underwriting firm of C. E. Unterberg, Towbin Company.

One of the most significant acquisitions in the computer industry in 1966 was Honeywell's purchase of Computer Control Company (3C). Shortly after the acquisition by Honeywell, the newly named Computer Control Division unveiled two new computers. The new integrated circuit machines, intended for scientific and process control applications, had been ready for announcement by 3C before news of the Honeywell acquisition.

New companies entering the field in 1966 were Business Information Technology (BIT) located in Natick, Massachusetts, and Interdata located in Eatontown, New Jersey. Both companies offer small-scale scientific computers priced below \$10,000. Interstate Electronics Corporation, with 10 years of experience in the electronic systems business, made its first entry into the computer field with the announcement of the model IEC-1010, a small-scale, scientific machine intended primarily for real-time control applications.

Computer Leasing Firms Prosper

The business of computer leasing drew much acclaim and scored impressive gains during 1966 with apparent encouragement from the top computer manufacturers. Although 80% of the computers now in use are leased rather than purchased outright, the practice of leasing applies predominantly to business oriented machines rather than small, on-line control computers. Purchase and lease-back of capital equipment through arrangements with financial institutions is a relatively old business practice, but it has not received much consideration from potential computer users until the advent of the computer leasing specialists. Computer leasing through a third party offers advantages to both the computer customer and the manufacturer. Under a third party lease arrangement, the leasing firm buys the computer outright from the manufacturer and then leases it to the user at a rate which is

COMPUTER MANUFACTURERS' PROFILE

at least 10% lower than the manufacturer's monthly rental fee. This reduces the user's monthly expenses and allows the manufacturers to recover the full purchase price of the equipment immediately rather than spreading revenues over the period of the lease, which often runs as long as five years.

Leasing firms operate on the premise that the useful life of current computer models is substantially longer than the period in which manufacturers normally expect to receive the full pay-off on leased equipment. If this premise is correct, the leasing companies can make a stable profit while recovering their investment over a period ranging from 5 to 10 years and still offer lower monthly rental fees than the computer makers.

Computer manufacturers are in persistent need of cash to offset high development expenses and to finance the costly research required to keep them in the competitive race. An unanticipated increase in the ratio of computer leases to outright sales can place the manufacturer in an unhealthy cash flow position. Control Data was the first major computer supplier to feel the adverse effect of an abrupt increase in the proportion of leased business to outright sales. To help relieve the cash flow problems induced by a high volume of leases, Control Data entered an agreement in June, 1966 with Leasco Data Processing Equipment Corporation. Under this agreement, Leasco buys Control Data systems at list prices and leases them on a long term basis. Control Data also revised its pricing structures to favor outright sales over leases. The most significant price revisions apply to Control Data's "super scientific" model 6600. The purchase price of the 6600 was lowered by 26% while the corresponding lease was reduced by only 5%. IBM also showed evidence of a pressing need for cash when it lowered System/360 purchase prices by 3% while raising lease prices by 3%. The pricing revision, instituted by IBM in October of 1966, actually favored the leasing companies since their initial investments are now lower, yet their lease rates are not necessarily changed.

There are now about a dozen companies offering computer leasing services and they now own an aggregate of about \$200 million worth of equipment out on lease. Individual leasing firms are listed in the Service Directory section.

Antitrust Studies

Another major development which took shape toward the end of 1966 was the decision by the Justice Department's antitrust division to launch a preliminary investigation of practices and policies of electronic computer manufacturers. Because of IBM's overwhelming 70% share of the computer business, most industry observers presume that IBM will be the prime target of the investigation.

Further government concern about possible antitrust and monopoly problems in the computer industry was more recently indicated by the House Antitrust subcommittee in March when it notified the major computer suppliers that it would conduct a separate study of industry practices. Letters were mailed to several computer manufacturers by the House subcommittee. The letter said the subcommittee's goal is to outline the current organization of the U. S. computer market, to determine each manufacturer's share of the world market, and to review current marketing and distribution practices of U. S. computer makers. The subcommittee reportedly asked each manufacturer to supply certain informa-

tion on computer marketing activities dating back to 1962. Some specific items requested in the subcommittee's letter included:

- Quantity and applicable model numbers for all computers sold or leased since December 31, 1966;
- Order backlog as of December 31, 1966;
- Names of current computer customers;
- Sales forecasts and reports of anticipated computer applications which were utilized in adopting current sales and distribution policies;
- Financial summaries covering operating costs, and profit and loss figures for computer manufacturing and distribution activities.

Whether or not any antitrust action is brought to court by the Justice Department is sheer conjecture at this point. And certainly no individual company would dare gamble its future on the assumption that a relaxed competitive climate will result from any antitrust action.

CORPORATE HIGHLIGHTS — 1966

Burroughs Corporation

Burroughs had total revenues of \$493,777,928 in 1966, up 7% from the previous year. Consolidated net earnings increased 77% to \$30,985,000. Burroughs, incorporated in 1905, is a major producer of office equipment, computers, data processing forms and supplies, space and defense systems, and electronic components. The Burroughs office equipment products primarily include accounting machines, adding machines, calculators, cash registering machines, and magnetic ink document processing equipment. Burroughs is the world's largest producer of accounting machines which, along with adding machines and calculators, accounted for \$295 million in world-wide revenues in 1966.

Commercial and military computers, magnetic tape equipment, disc memories, high-speed computer printers, paper tape readers and punches, and punched card equipment accounted for an estimated 25% of 1966 revenues. Revenues from the lease and purchase of commercial electronic data processing systems hit a new high of \$62 million during 1966.

As of the first of 1967, Burroughs had delivered over 1100 computers to commercial customers, and had a backlog of commercial orders in excess of 300 machines. Revenues from the computer operations are expected to show an annual growth rate of about 20% for at least the next five years. Compared to the other major EDP equipment manufacturers, Burroughs has a higher percentage (about 90%) of computers being delivered on lease as opposed to outright purchase. The computer operation is expected to be in the black by late 1968 or 1969; at which time, the leases can be expected to provide considerable stability to computer revenues.

Three new "third generation" computer systems were the major additions to the Burroughs' computer line during 1966. These include the medium-size B2500 and B3500 and the large-scale B6500. The B2500 and B3500 are due for delivery in the second quarter of 1967. First delivery of the B6500 is scheduled for the first quarter of 1968. Also announced in 1966 were 12 new disc file models.

Revenues from the Defense, Space and Special Systems Group amounted to \$57 million. Major contracts included a

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\$14 million contract from the U. S. Air Force for BUIC III, the third phase of a back-up interceptor control system for the North American continent's air defense. An existing airlines customer placed an additional order for 2,000 input and display systems. Other major awards in 1966 included a \$4.5 million B8500 computer system for the University of Wisconsin, and a \$7 million add-on contract from the U. S. Post Office for semi-automatic letter sorters. Burroughs is also participating with the U. S. Post Office to develop an electronic system for reading zip code numbers. A working model of an optical scanner developed by Burroughs is undergoing tests in a Washington post office. The Burroughs electronic components manufacturing plant at Plainfield, New Jersey continued to be a major supplier of core memory systems and the trademarked data system display devices known as Nixie tubes.

The company called for redemption of \$29,861,800 of convertible debentures in early 1966 resulting in an additional 765,705 common shares being issued. In May of 1966, Burroughs negotiated term loans of \$41.6 million with foreign and domestic financial institutions. The company announced plans to spend \$25.2 million for expansion in the United Kingdom, and the construction of a new manufacturing plant in Belgium. The company also plans to spend \$18 million for a new world headquarters complex in Detroit, Michigan which will house all of the company's executive offices and administrative activities.

Control Data Corporation

Consolidated sales, rentals, and service income of CDC amounted to \$96,949,656 for the six months ended December 31, 1966, as compared with \$73,704,850 in the same period last year. Net earnings for the six months ended December 31, 1966 were \$1,612,215 which amounted to \$0.15 per share of common stock. During the same period last year, CDC reported a loss of \$0.05 per share.

Significant operational highlights reported for the six months ending December 31, 1966 were two export licenses for 6600 computers to the French Power Bureau (Électricité de France), and S.I.A. (Société d'Informatique Appliquée). These orders were made possible through a licensing agreement between U. S. and French governments. Also, increased demand for CDC peripheral equipment was reported by President William C. Norris. During the last half of 1966, rumors spread through Wall Street concerning a possible acquisition of CDC by either Ampex, Honeywell, Philco or Westinghouse. CDC spokesmen staunchly denied the rumors of a take over. The firm denial left most of the financial community somewhat bewildered as CDC stock continued to climb from its 1966 low of 23½ to a high (as of March, 1967) of 56. One of the contributing factors to the sudden spurt in the price of the stock is perhaps due to reports of a \$10-million purchase of CDC disc files and other peripherals by Honeywell EDP Division. Also, rather large blocks of CDC stock were picked up by several mutual funds.

CDC reported that its performance for the fiscal year ending June 30, 1966, was severely impaired by a highly competitive computer field, technical problems and a significantly large proportion of lease business rather than outright sales. Sales for the year ending June 30, 1966 were \$167,613,943 with a net loss of \$1,912,154. Backlog as of the end of the fiscal year was 36% higher than June 30, 1965. The major

increase in the amount of the backlog was in lease contracts which comprise approximately 66% of total orders.

By June 30, 1966, nineteen 6000 Series computers (6600 and 6400) were installed and accepted on customer sites. Control Data is believed to be the only computer manufacturer installing computers in the so-called super-scale range. Deliveries of other manufacturers' super-scale computers are not expected this year. Some of the 6000 Series systems that will be installed during the fiscal year 1967 include Westinghouse Corporation (6600), NASA's Langley Research Center (two 6600's and a 6400), Lockheed Aircraft Company (6400), Smithsonian Institute Astrophysical Laboratory (6400), Aerospace Corporation (6400), and several large universities.

In May of 1966, CDC was awarded a \$22.7 million contract from the U. S. Post Office Department for the Postal Source Data System. Over 4000 units of Control Data equipment will be used in this vast communication-oriented system which will initially cover the 75 largest cities in the U. S. An additional development contract in connection with a "Continuous Letter Processing System" was awarded to CDC by the U. S. Post Office Department.

CDC was recently awarded an initial production contract by Hughes Aircraft Company for highly miniaturized computers for the Phoenix air-to-air missile program.

In addition to computer products, Control Data manufactures antenna systems, measuring instruments, lasers, and electrochemical devices. The company is also engaged in the development of sonar and navigational systems.

In February, 1966, Control Data concluded arrangements for a \$120 million revolving credit with ten major banks, led by Continental Illinois National Bank and Trust Company of Chicago. Under this credit arrangement, the company may borrow up to \$120 million over a two-year period. As of March, 1967, it was reported that \$87 million of this line of credit had been used, and that additional financing may be undertaken later this year.

Research, development and continuing engineering expenditures for the fiscal year were at a high of \$29.2 million, of which \$18.5 million (including costs deferred) was company financed, and the balance was performed for and financed by customers, including the U. S. Government.

In June, 1966, Control Data concluded an agreement, with Leasco Data Processing Equipment Corporation, which allows Leasco to buy CDC computing systems at list price and lease them to the customers on a long term basis.

Decision Control, Inc.

Decision Control was incorporated in 1956 and is currently headquartered at Newport Beach, California. Prior to 1961, the company specialized in providing consulting services for the data systems and computer fields.

In 1961, Decision Control began producing a line of digital logic modules. Subsequent announcements included core memory systems, data conversion equipment, and special-purpose systems.

About three years ago, Data Machines, Inc., a wholly-owned subsidiary was formed. The first product announced by DMI was the Data 620 computer, a small-scale scientific machine used in a variety of systems applications. First deliveries of the 620 began in November, 1965. About 60 Data 620 computers are now in operation, principally in real-time data acquisition and control systems. The number of

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shipments is expected to quadruple by the end of next year. The basic 620 sells for \$28.8 thousand. Nine months after the delivery of the first 620, the company's computer activities became profitable.

In March 1967, Data Machines announced the Data/620-I, which is offered at a basic selling price of \$13.9 thousand. The 620-I is functionally the same as the 620, however, the newer machine is designed with the company's new "Micro-VersaLogic" integrated circuit modules. Also, the 620-I housing is about one-third the size of the 620, and weighs only 40 pounds. According to Marketing Director, Burton A. Yale, the company plans to build about 85 Data /620-I computers this year, and about 350 next year. The production rate by year-end is expected to be 7 machines per week, according to Mr. Yale.

Other major product announcements by Decision Control in the past year have been the "VersaStore" core memory system, the "Microexec" hardware option for the 620 computer, and a special educational computer system designed for basic instruction in the organization and operation of digital computers.

Decision Control is a privately owned company and does not divulge annual sales information. It has been reported that the Data Machines Division accounts for a substantial share of total company revenues due to its increasing volume of computer sales. Decision Control currently employs about 200 people. Eighteen months ago, the company had 80 employees. To finance future growth, it appears likely that the first public offering of stock will be made in late 1967 or 1968.

Digital Equipment Corporation

In the fiscal year ended July 2, 1966, DEC's net income was \$1,950,540 on sales of \$22,776,434. The previous year's income was \$740,885 on sales of \$14,982,920. The 1966 results show a 52% increase in sales and a 163% increase in net profits. Sales for the six months ended December 31, 1966 totaled \$16,376,000 with net income of \$1,934,000 which was equal to \$0.66 per share. Net sales have increased every year since the company was founded in 1957.

Digital Equipment Corporation, headquartered in Maynard, Massachusetts, is controlled by Boston-based American Research and Development Corporation, a venture capital organization which now holds 60% of DEC's outstanding stock. In August of 1966, DEC made its first public offering of stock. The initial offering consisted of 375,000 shares at an offering price of \$22.00 per share. By March, 1967 the stock, traded on the American Stock Exchange, was as high as \$61 per share.

Primary products of DEC include small and medium-scale scientific computers, computer peripheral devices, digital logic modules, and equipment for testing computer components. Computers and related peripheral equipment account for about 75% of DEC sales, while logic modules account for about 20%. Sales to the U. S. Government in 1966 were less than 10%.

During the last year, Digital Equipment Corporation developed a whole new line of application-oriented computers based on the design of the successful PDP-8. These computers include the DISPLAY-8, the LINC-8, the TYPE-SETTING-8, and the new, SMALL-8 (PDP-8/s). The company also developed the PDP-9, and the medium-size PDP-10.

Eight PDP-6 systems, which range in price from \$350 to \$750 thousand, were installed during the year (total in use — seventeen). Deliveries this year were to Yale University, MIT's Laboratory for Nuclear Science, Stanford University, University of California at Berkeley, and the University of Rochester where it operates in tandem with a PDP-8. Several PDP-6's are now being used in time-sharing environments. The design of the newest of DEC's medium scale machines, the PDP-10, was greatly influenced by successful applications of the older PDP-6.

On January 31, 1967 Digital Equipment Corporation named Harry S. Mann as Financial Vice-President, Winston R. Hindle, Jr. as Product Group Vice-President for medium-large computers, Stanley C. Olsen as Product Group Vice-President for modules, and Nick J. Mazzarese as Product Group Vice-President for small computers.

Electronic Associates Incorporated

EAI reported net sales of \$28.4 million in the first nine months of 1966, up 35% from \$21 million in the same period in 1965. Unofficial reports place 1966 net sales near \$44 million. Orders received in 1965 totalled \$39,192,000 while net sales or completed contracts equalled \$32,614,365. Net income in 1965 was \$1,130,013 which was equivalent to \$0.51 per share.

Electronic Associates, headquartered in West Long Branch, New Jersey, was incorporated in 1945. Major products of the company include general-purpose analog, digital, and hybrid computers; X-Y recorders and plotters; display devices; and precision instruments. The company also maintains six computation centers in the U.S. and Europe which provide training and problem solving services. The major applications for EAI products include scientific computation and measurement by research and development organizations. Government related contracts accounted for 35% of 1965 sales.

The total annual market for general-purpose analog computers is estimated to be less than \$100 million. EAI has always been the leading supplier of analog machines, with no more than five other companies serving the same market. EAI's first hybrid computers (combination analog and digital) were produced in 1963 and they incorporated digital computers which were purchased from other suppliers. In 1965 EAI introduced its first digital computer, the EAI-8400. The 8400 forms the digital portion of the large-scale EAI-8900 hybrid computer which ranges in price from \$750 thousand to \$1.25 million. In October of 1966, EAI introduced its second digital computer, the small-scale EAI-640. The 640 is being offered by EAI for independent digital computation or for analog/digital applications. For the latter, the 640 is combined with the 680 analog computer to form the EAI-690 hybrid system.

The high costs associated with equipment and software development and initial production of EAI's new digital computers and hybrid system are the main cause for the substantial drop in earnings for the first nine months of 1966. Now that most of the production start-up costs are out of the way, EAI management expects smooth, high-volume production to commence along with modest improvements in profits.

In October, 1966, EAI announced a long-term loan of \$6.5 million in the form of 6½% promissory notes from

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institutional lenders. Proceeds were used to reduce short-term borrowing.

Having recognized the limited growth potential for analog computers, EAI has been building its digital computer capabilities since 1963. Part of this diversification program included the purchase of Pacific Data Systems in 1963. Further evidence of EAI's total commitment to the digital computer field is reflected in the realignment of the company's U. S. marketing organization. In January 1967, a marketing division and four separate product divisions were activated. The mounting importance of digital computer markets to EAI's future growth is noted in the new product line divisions; they include analog/hybrid computers, digital computers, control and information systems, and instruments.

EMR Computer Division

EMR Computer Division, formerly known as the ASI Computer Division of EMR, was acquired from Advanced Scientific Instruments, Inc. in 1963 by Electro-Mechanical Research, a Schlumberger company. ASI had been in operation since 1961. Although sales for the division are not itemized separately, approximate sales for 1966 were reported at \$8.5 million, up from \$3.5 million in 1965.

EMR Computer Division currently employs 250 people and is located in Bloomington, a suburb of Minneapolis. The division's first computer, the ASI-210, was introduced in 1962. The 210 was a high-speed, low-cost machine used for general scientific computation and for real-time control applications. The next machine to be placed on the market by ASI was the 2100, which was announced in 1963.

In late 1964, the Advance 6000 Series of machines was introduced. The first models in the 6000 Series were the 6020 and 6040. Both feature a 1.9 microsecond memory cycle time and both have a word length of 24 bits.

A typical 6020 customer is the Chemstrand Company, developer of synthetic fibers. The 6020 is being used to study the development of new man-made fibers. Central Exploration, an Oklahoma City geophysical firm, selected a 6040 for processing seismic records.

Other versions of the 6000 Series are the 6050 and the 6070. The latest computer announcement by EMR Computer Division came in April 1966 when the Advance 6130 was introduced. The selling price of the 6130 is approximately \$34 thousand for the basic configuration. A total of nearly 100 computers has been shipped since the founding of ASI.

Earle Wallick was recently appointed general manager of the Computer Division. Mr. Wallick was formerly general manager of the Photo-electric Division in Princeton, New Jersey. The former general manager of the Computer Division, John Paivinen, joined General Precision Semiconductor Division as Vice-President.

General Electric Company

GE sales for the year ended December 31, 1966 were \$7,177,255,730, up from \$6,213,594,781 reported for the previous year. Earnings per share for 1966 were \$3.75, compared to \$3.93 for 1965. Net income for 1966 was \$338,861,281, down from \$355,122,182 in the previous year. Earnings for the final quarter of 1966 were adversely affected by local strikes, work stoppages, and inventory imbalances.

GE is the largest domestic supplier of electrical equipment, and also maintains a leading position in the fields of electronics and atomic energy. The computer operations of General Electric represent a relatively insignificant portion of total revenues.

Even though GE was among the top five U.S. computer suppliers in 1966, its computer operations are still a drain on corporate revenues. Both the domestic and foreign computer operations are in the red due to heavy investments in new equipment designs and foreign affiliates, and because of deferred income resulting from an increase in equipment leases.

GE has had to re-examine its ambitious attempts to take a giant step into the European computer market. To get a running start on IBM's overwhelming lead in foreign computer sales, GE decided to buy its way into the market. The first step was the takeover of the French firm, Machines Bull in 1964. Since 1964, GE is reported to have poured more than \$100 million into the re-shaping of Compagnie Bull-GE, its marketing force, and Société Industrielle Bull-GE, the manufacturing facility. The initial outlay was a modest \$45 million.

A similar venture was launched in Italy in 1964 when GE bought a 75% controlling interest in Olivetti for \$12 million. By comparison, the Olivetti operation is in better shape with production and sales of the Model 115 computer reported to be running smoothly. However, the Olivetti operation is still in the red.

Despite the temporary setbacks and the problems which GE was quick to recognize, most industry sources feel that profitable operations will be reported in the near term.

In the U.S., GE has also been forced to cutback on computer development activities in order to relax the strain on corporate resources. About 500 employees have recently been laid off at the computer manufacturing facility at Phoenix. Also, more scrutiny is being given to new computer product plans according to company spokesmen.

GE's current computer line covers a broad range of small, medium, and large scientific and business data processors. Deliveries of the GE-115, a small-scale business data processor, began in April, 1966. Customer reaction to the 115 appears extremely favorable since an estimated 900 systems have been ordered. For process control applications, GE offers four models in its GE-PAC/4000 series. Units in the large-scale 600 series are being installed in several locations throughout the U. S. for use in commercial time-sharing facilities.

Honeywell, Inc.

Honeywell's world-wide 1966 sales were estimated at \$910 million, up 24% over 1965. The fastest growing segment is the computer business which had 1966 sales and rentals of \$182 million, or 20% of the company's business, compared with 1965 sales and rentals of \$104 million. The company's computer business is based in the Boston area with more than 8100 employees.

The EDP division passed a major milestone in 1966 when its domestic computer business became profitable. According to board chairman James H. Binger, this accomplishment resulted from important innovations in the computer field consisting of long-term leasing and the sale and lease-back of computers. During 1966, the company sold and leased back computers valued at \$40 million. Unlike the other major computer suppliers, Honeywell's leases are not ar-

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ranged through leasing firms. Last year, Honeywell sold \$40 million worth of computers to a group of banks and then leased them back to rent to Honeywell's customers.

The total value of computers shipped in 1966 rose sharply to approximately \$300 million, compared with \$205 million in 1965. At year end, there were some 2000 Honeywell computers installed or on order around the world.

On May 25, 1966, the stockholders of Computer Control Company, Inc. (3C) confirmed an agreement, previously announced on March 25, by over a two-thirds vote to transfer all assets of 3C to Honeywell on the basis of one share of Honeywell common stock for each three-and-a-half shares of 3C common.

3C, founded in 1953, employs about 1300 people at plants in Framingham, Massachusetts; Peterboro, New Hampshire; and Los Angeles, California. 3C sales in the past ten years have grown from less than \$1 million to \$23.7 million in the last full fiscal year of operation which ended October 30, 1965. 3C has invested heavily in integrated circuit technology and continues to be a major producer of digital logic modules, core memory systems, and small to medium-scale scientific computers. The merger resulted in the formation of a Computer Group, headed by Walter W. Finke. The new Group consists of two divisions; The Electronic Data-Processing division directed by C. W. Spangle, and the Computer Control Division, headed by Benjamin Kessel as vice-president and general manager. Mr. Kessel had been president of 3C before the acquisition. On June 8, 1966 Chairman Binger announced the transfer of the industrial process control computer activities from its Industrial Products Group to the newly-formed Computer Group. Computers supplied by the new Computer Control Division will replace the H-21 computers formerly produced by the Industrial Products Group.

On October 25, 1966, the Computer Control Division (CCD) introduced the small, low-cost DDP-516 computer which was offered for immediate delivery. Before year-end, the Computer Control Division unveiled another micro-circuit machine, the DDP-416.

In early 1967, director and group vice-president Walter W. Finke was elected president and chief executive officer of the Dictaphone Corporation.

Honeywell's twenty-five-year 5.60% sinking fund debentures, due 1992 were oversubscribed at par. The proceeds are to be used for business expansion and the retirement of short term debts.

Interdata, Inc.

Interdata, incorporated in July 1966, entered the rapidly growing small-scale computer field with the announcement of the company's \$6,000 Model 3. Located in Eatontown, New Jersey, Interdata was founded by Daniel Sinnott (President), Arthur Furman, and Peter Stearns. The founders were formerly employed by Electronic Associates, Inc. where they were associated with digital computer development activities.

According to marketing director, James H. Buzzell, Jr. "Interdata's overall product development objective was to establish a low cost, modular computer family with programming and peripheral compatibility between each of the members of the family." Interdata expects the principal uses of the new Model 3 computer to be in switching sys-

tems, process control, automatic test and inspection systems, numerical control systems, data acquisition systems, and the newly developing computer educational market. According to Buzzell, Interdata has already booked over 50 orders for the Model 3 and sales for 1967 are expected to be over \$1 million. First deliveries started in March, 1967.

International Business Machines Corp.

IBM's consolidated gross income from world-wide operations in 1966 was \$4,247,706,091, an increase of \$674,881,372 over 1965. IBM's earnings for 1966 were \$526,130,192, up \$49,227,702 over the prior year. Net earnings for 1966 amounted to \$9.66 per share compared to \$9.03 for the previous year. Foreign operations showed gross income of \$1,318,099,225, an increase of \$232,593,474 over 1965. Earnings from foreign operations for 1966 were \$174,605,772, an increase of \$30,579,442 over the previous year.

Among other operational highlights for 1966, IBM reported that:

- World-wide rate of production on System/360 exceeded 1,000 systems per month;
- Upon completion of two new plants abroad, 22 manufacturing locations and 13 laboratories around the world will be engaged in the production and development of System/360's;
- Manufacturing and laboratory space was increased by 3 million square feet;
- Total assets at year end amounted to \$4,660,778,651.

A general breakdown of 1966 sales shows that sales, service, and rentals of data processing equipment accounted for 76% of gross income. Other regular products and services accounted for 20%, and aerospace and defense orders contributed 4%.

The first System/360 Model 75 was delivered in January 1966, and the first Model 67 was delivered in June, 1966. IBM continued to expand the System/360 by introducing a variety of new peripheral units which were added to the 44 devices originally announced for use with the basic computer models. The Model 20, smallest 360 system, was expanded through the addition of two direct access auxiliary memories that can store up to 10.8 million characters on magnetic discs. Also announced was a new input device, the IBM 1287 Optical Reader, which can read hand-printed numbers and five hand-printed alphabetical characters from a variety of source documents and enter the information directly into a System/360 for processing.

Last year, the Company developed and released more than 125 new program packages. A typical program package is Retail IMPACT which allows large retail organizations to monitor the movement and sale of inventory items while automatically producing reorder documents and sales reports.

Numerous other products in the field of information handling were announced or delivered by the company during 1966. In June, the low-cost IBM 1130 computer was first delivered. This small computing system was designed for individual use by engineers, scientists, and mathematicians.

The IBM 1800 Data Acquisition and Control System, primarily used for industrial process control, was delivered to customers. Another data acquisition system, the IBM 1080, was announced and a prototype installed in an Ohio hospital. The System 1080 is designed to help speed the computation and reporting of laboratory test results.

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In May, IBM announced a new industry information service which provides computer-generated market research reports based upon electronic banks of data. IBM will use Dun and Bradstreet material which contains statistics on some 390,000 businesses throughout the country. Another data bank, currently being compiled by IBM, will be a detailed model of the national industrial economy, tracing the flow of goods and services among manufacturers.

DATATEXT, first marketed during 1966, is a text-editing capability that allows a number of customers at different locations to use the same computer for preparing, storing, and revising business and technical reports ranging from legal documents to sales proposals. The customer is provided with a typewriter-like terminal unit in his office which is linked to a central computer owned and managed by IBM. DATATEXT centers were opened in San Francisco, Los Angeles, New York, and Cleveland.

Also introduced and demonstrated was the IBM 9370 Document Reproducer which is an offset duplicator that uses rolls of paper and can reproduce on both sides of the paper at the rate of 50,000 impressions per hour.

The company began deliveries of its document viewers which are used for the display of microfiche. Microfiche is a miniature microfilm sheet, about the size of a punch card, containing up to 90 individual page images. Each image can be magnified larger than original document size.

The Service Bureau Corporation, a wholly owned and independently-operated subsidiary of IBM, installed more than 30 System/360s during 1966, as it began establishing its nationwide network of interconnecting data processing centers. In 1969 the network is scheduled to be fully operational and will comprise more than 125 IBM System/360's interconnected by over 181,000 miles of leased private lines.

Science Research Association, Inc., a wholly owned subsidiary of IBM, showed continued progress in 1966. The company publishes instructional materials, learning systems, guidance materials, and educational and psychological tests for schools, government, and industry.

NASA awarded IBM an additional five-year contract for the installation of System/360's to replace five IBM 7094 computers. The 360's will be used by NASA's Manned Spacecraft Center at Houston for the Apollo/Saturn Program.

On January 25, 1966, the Board of Directors elected three principal officers of the company to new posts. Mr. Albert L. Williams, President of the Company since 1961, was elected Chairman of the Executive Committee of the Board of Directors. Mr. T. Vincent Learson, Senior Vice-President, was elected President of IBM to succeed Mr. Williams. Mr. Arthur K. Watson, also a senior Vice-President, was elected Vice-Chairman of the Board of Directors.

National Cash Register Company

For the year ended December 31, 1966, NCR income from sales, services, and equipment rentals totalled \$871,305,000, up from \$736,849,000 for the previous year. Net income for 1966 was \$27,219,000 or \$3.10 per share, compared to \$24,725,000 or \$2.81 per share for 1965. At year end, NCR employed a total of 79,000 people and had 26,266 stockholders.

Domestic earnings rose from \$13,069,000 in 1965 to \$13,579,000 last year. Total after tax foreign earnings increased

from \$16,353,000 to \$18,683,000.

The company reported that international sales results were favorably influenced by Australia's changeover to a decimal currency, which is requiring the conversion or replacement of some 80,000 NCR business machines.

Although a heavy volume of deliveries of all products was reported for 1966, record income was received from equipment rentals, services, and the sale of business forms and supplies used with the NCR products. Although no breakdown of sales was provided, record gains were reported for computer systems, sales registers, and accounting and adding machines.

NCR installed a record number of "total" systems in retail stores during 1966. In these systems, control registers are linked to NCR computers to provide an integrated complex for inventory control, accounts receivable, and management control. The company reported favorable customer reception of the 315 Series of computers, the smaller 500 Series of computers, and the 395 line of electronic accounting machines.

As noted by chairman Robert S. Oelman, the sales growth in 1966 was somewhat offset by the expanding lease/purchase ratio which is causing a substantial deferral of income. Chairman Oelman reported that 1966 sales were up 18% while income was up 10%. Since the company's entry into the equipment rental business, a total of \$182,027,000 has been invested in rental equipment world-wide. The depreciation on such equipment to date has totaled \$78,200,000. During 1966, the company's capital expenditures totaled \$114,926,000. Of this amount, approximately \$67,240,000 was invested in equipment for rental to customers.

During 1966, NCR entered a new field with the introduction of PCMI (trademark) Microform Systems. This equipment permits the storage of up to 3,200 business documents or pages of information on a single transparency the size of a postcard. Further inroads were made in this field in February, 1967, when NCR acquired Microcard Corporation, a leading firm in the field of microfiche information storage systems. The acquisition involved the issuance of 65,000 shares of NCR common stock.

Company research and development expenditures in the six years through 1966 totaled 134.5 million. The result is a line of computers, including the 304, 310, 315, and 390. Recent additions are the 315 Rod Memory Computer which uses a thin film memory, and the Series 500 family. The U. S. Army announced that NCR is supplying it with 18 mobile computer systems (Series 500) for assignment to logistical units to mechanize the inventory control of repair parts for Army equipment.

Radio Corporation of America

RCA consolidated sales for the year ended December 31, 1966 were \$2,561,640,000, up from \$2,057,117,000 for the previous year. Net profit for the year was \$132,407,000 or \$2.22 per common share compared to earnings of \$101,161,000 or \$1.73 per share in 1965.

RCA's electronic data processing business showed a minor loss for the year. New domestic bookings for the third generation Spectra 70 computers reached an all-time high exceeding the previous year by more than 40 per cent. Reasons given for the 1966 loss reported for the computer operations were an increase in the number of customer leases over outright purchases and an RCA management decision,

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based on the immediate success of the Spectra 70, to increase expenditures to accelerate development of data processing equipment as a major component of the company's long-range growth. Elmer W. Engstrom, Chairman of the Executive Committee, and Robert W. Sarnoff, President, recently stated that "RCA intends to take full advantage of the success of its current models, to pursue new avenues of growth in the expanding data processing industry, and to obtain an increasing share in the computer market." The company's share of all computer sales to date was estimated at 3.2% at year end.

RCA's full-scale entry into the field of computer-based instruction, representing the first major joint undertaking of its kind by industry and education, was announced in March 1967 by Mr. Sarnoff. Mr. Sarnoff also announced the formation of a new activity, RCA Instructional Systems, which will spearhead the development of computer-based techniques designed to overcome some of the nation's most pressing educational problems. Alan B. Corderman has been appointed Director of RCA Instructional Systems, with headquarters in Palo Alto, and will work closely with a group of nationally-known Stanford University educators, headed by Dr. Patrick Suppes, a pioneer in computer-based instruction (CBI).

Mr. Sarnoff said the new technology will combine computers, communications channels, and display terminals into a system capable of teaching the student as an individual, rather than an arbitrary norm. He noted that Random House and its educational subsidiary, the L. W. Singer Company, will play an important role in the new project.

RCA's activities in the data processing field date back to the 301 computer which was first delivered over six years ago. Later models included the larger 3301, the 501, and 601. First deliveries of the Spectra 70 Series began in the fourth quarter of 1965. Models in the Spectra 70 Series include the 15, 25, 35, 45, and 55. Profitable operations of the EDP division were reported for 1964 and 1965.

In May 1966, RCA acquired Random House, a leading book publisher with sales of \$36.1 million and earnings of \$1.38 million in its last full year of operation. Also in the past year, RCA acquired Hertz Corp. the leading firm in the car and truck rental and leasing business.

Raytheon Computer Division

Consolidated sales for Raytheon Company for the year ended December 31, 1966 were \$709 million, up from \$487.8 million for the previous year. Earnings for 1966 amounted to \$18.4 million, or \$2.90 per common share, compared to \$11 million and \$2.25 per share for 1965. Raytheon president Thomas L. Phillips predicted that 1967 sales will rise to about \$825 million.

Annual sales for the Raytheon Computer Division, which was formerly Packard Bell Electronics, are estimated at less than \$10 million. For the past 2 years, Raytheon Computer has been marketing the 520 computer, a medium-scale scientific machine used in special systems applications. The Computer Division has delivered an estimated twenty-five 520 systems to outside customers.

While President Phillips recently commented that the company's computer operations are achieving "some degree of success", the Computer Division has not enjoyed the same order volume as some of the small independent companies

which offer a similar class of machine. To bolster computer sales and to capitalize on one of the faster growing segments of the computer industry, it can be reasonably predicted that Raytheon Computer Division will soon unveil a small-scale, scientific machine about one-third the price of the 520.

Scientific Control Corporation

Scientific Control Corporation, a privately owned company was incorporated in May 1964 in Dallas, Texas. Principals of the company include John B. Baird, President; George A. Zimmermann, Vice-President Marketing; Donald G. O'Neal, Vice-President Engineering; and James H. Boyd, Vice-President Manufacturing.

In the year ended May 1, 1966, SCC sales were approximately \$1 million. Sales for the year ending May 30, 1967 are expected to be double the previous year.

In May 1965, SCC moved to a new 10,000 square foot manufacturing facility in Dallas. Since then, the number of employees has grown from 9 to 80 people. About 20% of the employees are engineers.

The first computer to be announced by the company was the SCC-660 which was introduced in May, 1965. At the same time, a line of telemetry and signal conditioning equipment was announced.

The SCC computer line currently consists of the 650, 655, 660, 670, and 6700. The first large order received by the company was for a model 670 system. This order was placed by McDonnell Aircraft Corporation. Other key customers include Monsanto, California Institute of Technology, Martin Company, and Argonne National Laboratories.

The latest computer offering from SCC was made in December 1966 when the 6700 time-sharing system was announced. The basic 6700 system is priced at \$420 thousand while a typical configuration sells for about \$1 million.

SCC has received orders for 18 computers as of March 10, 1967. In the eight-month period ending March 1, 1967, SCC has delivered 12 computers.

As explained by marketing vice-president George A. Zimmermann, most of the SCC computers are used in large data acquisition and control systems. According to Mr. Zimmermann, these types of systems generally require signal conditioning and special engineering to interface the company's computers to customers' equipment. Mr. Zimmermann stated further that SCC welcomes jobs requiring custom interfacing for the many types of computer peripheral devices.

Scientific Data Systems, Inc.

For the year ended December 31, 1966, SDS reported sales of \$55,500,000 with net income of \$4,300,000. In the previous year, sales totaled \$43,999,000 with net income of \$3,759,000. Net income per common share for 1966 was \$1.89, up from \$1.69 per common share in 1965.

In 1961, SDS began producing a line of low-cost, high-speed scientific computers designed primarily for integration into larger special-purpose systems. The first computers offered by SDS were the small-scale 910, 920, and 930 models. Later models included the 925, 940, and 9300. The first SDS machine to employ integrated circuits was the 92. In March 1966, SDS introduced a third generation family of machines known as the Sigma series. The Sigma an-

nouncement represents the first concentrated effort by SDS to go after that segment of the computer market which requires general purpose computational equipment. While other manufacturers were preparing to fill supposed capability gaps in IBM's newly announced System/360 family, SDS claimed to be readying a machine with more than twice the computational power per dollar than any other third generation machine.

The first member of the new family of SDS machines to be announced was Sigma 7. So far, Sigma 7 is the largest member of the family and the monthly rentals range from \$5 thousand to \$25 thousand. Purchase prices range from \$100 thousand to almost \$1 million. Sigma 7 is considered a medium-scale machine with both business and scientific processing capabilities. Software to be offered with Sigma 7 includes FORTRAN, PL/1, COBOL and various monitors including a time-sharing monitor. A rather significant marketing innovation of SDS is the company's policy of offering COBOL, a business oriented programming language, on an optional basis. The SDS customers with business data processing applications can elect to buy the COBOL package as a separate option. The company feels that customers having only scientific applications should not be required to pay for software they would never use.

Sigma 2 was the next member of the new family which was announced in August 1966. This was followed in January, 1967 with the Sigma 5 announcement. Sigma 2 is a small, low-cost, real-time computer for scientific, engineering, and process control applications. The basic purchase price is about \$26 thousand. Sigma 5 is a medium-size machine offered for both scientific and business applications. Price of the basic Sigma 5 is \$90 thousand.

Deliveries of the Sigma 2 and Sigma 7 began in December, 1966. Deliveries of Sigma 5 are scheduled to begin in August 1967.

SDS negotiated an agreement with a financial institution for the purchase of up to \$15,000,000 of SDS leased equipment, therefore effecting a more favorable sales/lease ratio and realizing profits that would normally have been deferred. The company, late in 1966, issued \$125 million in 5½% debenture bonds convertible into common stock at \$53 per share.

SDS stock became listed on the New York Stock Exchange during 1966. The 1966 low was quoted at 41 and the high as of March 10, 1967 was 110.

In addition to Max Palevsky, SDS currently employs about 2900 people and is headquartered in Santa Monica, California.

Standard Computer Corporation

Standard Computer Corporation was incorporated in March of 1965 in Phoenix, Arizona by D. E. Keefer, G. W. Joithe and L. L. Rakoczi. President of the new company is Roger T. Hughes, who had been employed by IBM for the past six years. Keefer and Rakoczi are former GE computer designers. In September of 1966, Standard moved to Santa Ana, California where it established manufacturing facilities. The company has announced and has made initial deliveries of its first computer. The new machine, designated the IC-6000, is described by the company as a "language independent, computer-within-a-computer".

Standard Computer Corporation obtained its equity capital of over \$725,000.00 through the sale of no-par com-

mon stock and debenture bonds with warrants. The shareholders recently voted to increase the authorized no-par common stock from 1,500,000 shares to 5,000,000 and split 2-for-1 the 1,333,344 shares outstanding of record December 9, 1966. The stock split will also double the number of shares optioned through warrants to debenture holders.

Standard Computer Corporation offers several models of the IC-6000 at rental prices ranging from about \$9 thousand to \$23 thousand per month. The purchase price ranges from \$420 thousand to \$850 thousand.

As announced by President Hughes, the IC-6000 is a third generation computer which is specifically designed to use second generation software. A small, high-speed processor within the computer functions independently thereby allowing the IC-6000 to interpret a variety of machine languages without degrading the performance capability of the main memory.

The term MINIFLOW has been coined by the company to designate the concept of an independent computer-within-a-computer. According to Mr. Hughes, the basic machine is capable of handling every requirement of the IBM 7094 Series and/or 7044 Series. FORTRAN, COBOL, SORT and UTILITY programs are executed on the IC-6000 with 100% compatibility.

Production versions of the IC-6000 have been delivered late last year to customer installations in New York and Los Angeles.

The IC-6000 has been under development for two years, and employs Fairchild CTL integrated circuits. Standard Computer expects to sell about 25 systems during 1967 and also plans to establish a national sales force, according to Mr. Hughes.

In commenting on the industry's need for the IC-6000, Mr. Hughes pointed out that the current trend lines of costs for computer users have been shifting dramatically from hardware to software. In 1955, 80% of the cost was hardware (machine) related with 20% relegated to software (programming). By 1965, the relationship had become 50% hardware and 50% software. If the trend were to continue, 1975 would see a complete reversal with 20% going to hardware and 80% of costs accruing to software.

Systems Engineering Laboratories, Inc.

SEL reported total sales of \$6,163,267 for the fiscal year ended June 24, 1966, up from \$5,254,083 for the previous year. A net loss of \$403,053 was reported for fiscal year 1966 compared to net income of \$470,489 for the previous year.

For the first half of the fiscal year 1967, ended December 9, 1966, sales totaled \$2,745,215 with a net income of \$82,200 or \$0.09 per share. For the same period in 1965, the company reported sales of \$2,087,231 and a net loss of \$253,112 which was equivalent to a loss of \$0.27 per share. At the end of the second fiscal quarter, SEL reported a backlog of orders valued at \$5,500,000, the highest mid-year level in the company's history. Sales for the year ending June 30, 1967 are expected to reach \$8 million.

SEL, headquartered in Fort Lauderdale, Florida, was founded in 1961, and currently employs about 400 people. About 20% of SEL employees are engineers, and 45% of employees are shareholders in the firm. In 1961, the SEL founders purchased 2% of the original capital stock of the company (2,940 shares of common stock) for a total price

COMPUTER MANUFACTURERS' PROFILE

of \$294,000. After a 100-for-1 stock split in October 1963, and 1.2-for-1 stock distribution made in September 1965, such shares now comprise 646,800 shares of common stock.

The first public offering of SEL stock was made in March, 1966 when 120,000 shares were offered at an initial price of \$7.00 per share. The low for calendar year 1966 was \$5.00 and the high as of March 10, 1967 was \$21.00 per share.

SEL produces measurement, processing, and control equipment. The company's business is divided into three general categories — systems, products, and services.

Until mid-1965, the SEL product line consisted of amplifiers, multiplexers, analog-to-digital conversion equipment, and computer memory units. These products represented the components of customized systems which SEL adapted for specific customer requirements such as telemetry data acquisition, control of industrial processes, and monitoring test operations performed on aerospace equipment.

To replace specialized control units previously utilized in SEL systems, and to meet new customer demands, the company decided to invest in the development of a series of general-purpose, digital computers. The unanticipated start-up costs for the development of equipment and associated programming systems were the major contributing factors to the reported net loss for fiscal year 1966.

Resulting from SEL's computer development effort was the 800 series of integrated circuit machines. Current models in the series include the small-scale SEL-810A, and the medium-scale SEL-840A. The bulk of development and start-up costs are now reported to be out of the way, and production has commenced on a smooth basis. About 70 computers in the 800 series have been delivered or ordered as of March, 1967.

Major new products announced last year include a multi-programming computer system designated the SEL-840MP; a monitor programming system which facilitates time-sharing applications of SEL computer systems; and Accureed (trademark), a new multiplexer which is said to offer significant improvements in the dynamic range capabilities required for high-speed sampling of low-level signals.

In the past year, SEL has opened sales and service offices in Boston, Cleveland, Orlando, Houston, San Francisco, and Huntsville, Alabama. Other SEL branch offices are located in Los Angeles, and Washington, D. C. Also during the past year, Emil R. Borgers was elected Vice-President-Programming, and Seymour Schwartz was appointed Director of Programming. Both executives were formerly employed at Scientific Data Systems.

Univac Division of Sperry Rand Corporation

Consolidated sales for Sperry Rand Corporation were \$1,079,677,000 for the nine months ended December 31, 1966, compared with sales of \$893,590,000 in the same period of the previous year. The company reported record earnings of \$39,330,000 or \$1.26 per common share for the nine-month

period. In the similar nine-month period of 1965, the company earned \$20,045,000 or \$0.64 per common share.

The company reports that substantial gains by the Univac Division contributed significantly to the improvement over last year's nine-month period. The first profits realized by the Univac Division came during the last five months of the fiscal year ended March 31, 1966. Business machines, peripheral equipment, and related supplies accounted for about 35% of the company's sales in the year ended March 31, 1966.

Univac, holder of second place in the computer industry since the early punched card days, announced in mid-1966 its new, third generation family of machines, the 9000 series. The first two models to be announced were the 9200 and 9300 with first shipments scheduled for mid-1967. At the time of the initial announcement, a model 9500 was promised as the next member of the compatible 9000 series.

Based on sales value of all computers shipped to date, Univac remains in second place with a market share of 6.6%. However, for sales during 1966, Univac dropped to fourth place with 5.3% while Honeywell captured second place with 7.4%, and Control Data moved to third place with 5.5%.

Although sales for the fiscal year ended March 31, 1967 were not available at time of publication, the figure is expected to be about \$1.4 billion compared to last year's \$1.28 billion. Hydraulics, farm equipment and shavers are expected to account for about \$400 million or about 28% of all 1966-67 sales. Yet, if the net profits on these products are consistent with the recent past, they will account for more than 75% of total net earnings for fiscal year 1967. Industry sources claim that future growth in Sperry's earnings depends largely on the ability of the Univac Division to show further improvements and to move further into the black. The many management changes and organizational realignments in recent years are a reasonable basis for the expectation that the Univac Division will move well beyond its current position of marginal profits.

The company continues to pioneer in the real-time computer field as evidenced by the award of a contract from United Air Lines, valued at \$39 million. This job was landed in fiscal year 1966 and calls for a totally integrated reservations, operations, and management information capability. The system will link all 116 cities served by United. Univac systems now serve a dozen of the world's leading airlines.

Another significant contract was awarded in January 1966 to the Univac Division by Bache and Company, one of the nation's largest stockbrokers. The Bache contract, valued at \$3 million, is said to be the largest real-time system ever ordered by a brokerage firm. The system will provide branch offices with immediate access to files containing over 250 million characters of information, and will enable the firm to handle message traffic at the speed of six-thousandths of a second for the average buy or sell order.

The corporate and financial information contained in this section has been obtained from a variety of sources believed to be reliable, including company annual reports, financial news releases, product manuals, and company spokesmen. However, accuracy and completeness are not guaranteed. Neither the information presented nor any opinions expressed constitutes a solicitation by the publisher to buy or sell any securities. The quarterly updating supplements of COMPUTER INDUSTRY ANNUAL will include new reports (both annual and period) of sales and earnings as they are released.

COMPUTER INDUSTRY ANNUAL'S MARKET SURVEY

RESULTS TO DATE — APPROX. 13% RETURN

The Questionnaire

During the first part of January 1967, the publishers of COMPUTER INDUSTRY ANNUAL sent questionnaires to approximately 3000 manufacturers and service companies associated with the field of computers and data processing. The questionnaire listed the same products and services as are listed in this issue's Product and Service Directories.

The questionnaire contained the following instructions:

1. **DO NOT** identify your company on this questionnaire. Return the completed questionnaire in the enclosed postage-paid envelope.

2. Please examine the entire list of products and services. After each product which your company markets, indicate the dollar sales volume and the number of units sold in calendar 1966. Use round figure estimates.

As of the date this section was prepared for publication, approximately 400 completed questionnaires were returned, representing approximately 13% returns.

The Results To Date

The actual results to date, product-by-product, are given below. Of course, for many of the products where an extremely low response was received, the figures given below are of little value. However, one of the major reasons for presenting these partial returns is to illustrate what we are trying to accomplish and to allay, further, fears that we are interested in specific company sales figures. As noted above, respondents were not required to put a company identification on the completed questionnaire.

We believe that this is the first organized effort to pinpoint sales statistics on an individual product-by-product basis for industry-wide reporting. Although it is an ambitious and difficult undertaking, it is well worth the effort. A significant return would be invaluable to just about everybody associated with the industry.

The publishers of COMPUTER INDUSTRY ANNUAL will be conducting this market survey on a continuous basis and further responses will be reported in our updating supplements. We hope that this section in the 1968-69 edition of COMPUTER INDUSTRY ANNUAL will fully justify our efforts.

Market Survey — Partial Results (13% return)

CALENDAR 1966

Product	No. of Units	\$ Volume (in millions)
1. CHARACTER RECOGNITION EQUIP.		
IMPRINTERS, magnetic ink character	20	0.5
IMPRINTERS, optically-sensed character	150,000	4.5
MARK SENSING EQUIPMENT	2	0.006
READERS, magnetic ink character	—	—
READERS, optical character scanning	29	3.7
2. CIRCUITS AND MODULES		
CIRCUIT MODULES, digital logic; discrete (germanium)	11,000	0.810
CIRCUIT MODULES, digital logic; discrete (silicon)	14,000	1.00
CIRCUIT MODULES, digital logic; hybrid (integrated and discrete)	30,000	0.370
CIRCUIT MODULES, digital logic; integrated silicon monolithic	13,500	1.275
CIRCUIT MODULES, digital logic; integrated, thin-film	—	—
INTEGRATED CIRCUITS, silicon monolithic (without circuit boards)	1,063,900	3.728
INTEGRATED CIRCUITS, thin-film (without circuit boards)	—	—
3. COMPUTERS AND CALCULATORS		
CALCULATORS, electronic, desk-top	7,342	14.443
COMPUTERS, general-purpose analog	20	0.500
COMPUTERS, general-purpose digital	304	9.290
COMPUTERS, hybrid	14	8.00
4. DATA COMMUNICATIONS EQUIPMENT		
COMMUNICATIONS PROCESSORS, stored-program, switching-buffering	25	1.00
COMMUNICATIONS PROCESSORS, special purpose, single-channel controllers	12	0.80
COMMUNICATIONS PROCESSORS, special purpose, multiple-channel controllers	5	0.20
DATA TERMINALS, block-by-block, magnetic tape	90	2.37
DATA TERMINALS, block-by-block, multi-purpose	—	—
DATA TERMINALS, block-by-block, paper tape	2,895	7.10

CI ANNUAL'S MARKET SURVEY

Market Survey — Partial Results (13% return)

CALENDAR 1966

Product	No. of Units	\$ Volume (in millions)
DATA TERMINALS, block-by-block, plotter	—	—
DATA TERMINALS, block-by-block, printer, high-speed	417	2.379
DATA TERMINALS, block-by-block, printer, medium speed	—	—
DATA TERMINALS, block-by-block, punched card	2	0.050
DATA TERMINALS, block-by-block, teleprinter	30,797	38.20
DATA TERMINALS, inquiry response, alphanumeric keyboard	15,852	11.8
DATA TERMINALS, inquiry response, audio response	—	—
DATA TERMINALS, inquiry response, badge-token readers	—	—
DATA TERMINALS, inquiry response, CRT with keyboard	—	—
DATA TERMINALS, inquiry response, point-of-sale	—	—
DATA TERMINALS, inquiry response, special purpose	—	—
MODEMS, data communications	30	0.12

**5. DATA SYSTEMS COMPONENTS,
EQUIPMENT, AND MATERIAL**

AMPLIFIERS, dc	2,250	0.455
AMPLIFIERS, instrumentation	3,600	1.71
AMPLIFIERS, operational	40,500	3.025
BLOWERS, FANS, cooling assemblies	48,600	3.22
BUS BARS AND ASSEMBLIES	167,700	3.02
CABINETS, ENCLOSURES, CONSOLES	68,500	7.5
CABLE AND WIRE, coaxial flexible	20 mill. ft.	1.0
CABLE AND WIRE, fine lead	700 mill. ft.	4.0
CABLE AND WIRE, flat flexible	3 mill. ft.	2.5
CABLE AND WIRE, multiconductor	2 mill. ft.	4.0
CABLE AND WIRE, shielded dc power (not coax.)	1 mill. ft.	2.0
CAPACITORS (all types)	10,727,000	5.816
CHASSIS, SLIDES, RACKS	85,482	1.689
CIRCUIT BOARDS, ETCHED (without components)	5,918,000	9.084
CLAMPS AND CLIPS, cable	—	—
CLIPS, TEST (alligator)	—	—
CLOCKS, digital, real-time	160	0.28
COMMUTATORS, switching	1000	0.15
CONDUIT, electronic systems	—	—
CONNECTORS, cable-to-chassis	209,000	0.830
CONNECTORS, circular, cable	2000	0.0250
CONNECTORS, pc and IC board	6,156,600	8.238
CONVERTERS, analog-to-digital	297	1.535
CONVERTERS, binary-to-decimal	15	0.015
CONVERTERS, dc-to-frequency	3,350	0.420
CONVERTERS, digital-to-analog	251	0.310
CONVERTERS, digital-to-synchro	34	0.141
CONVERTERS, frequency-to-dc	250	0.131

Product	No. of Units	\$ Volume (in millions)
CONVERTERS, synchro-to-digital	7	0.101
CONVERTERS, voltage-to-frequency	250	0.120
CORDS, patch	48,000	0.05
COUNTERS, decade	1,750	0.852
COUNTERS, readout indicator	1,040	0.517
COUNTERS, up-down	201	0.202
CRYSTALS, quartz (for freq. control)	261,500	1.256
DELAY LINES, glass	2,000	0.3
DELAY LINES, magnetostrictive	20,000	1.2
DIODES, germanium	132,658,500	8.80
DIODES, photoelectric	520,000	0.58
DIODES, silicon	57,292,000	5.70
DIODES, tunnel	—	—
DIODES, Zener	251,715	0.92
ENCODERS, shaft-angle	—	—
EXTRACTORS, circuit board	6100	0.125
EYELETS, circuit board	300,000,000	0.45
FIBER OPTICS ASSEMBLIES (for punched code readers and mark sensors)	510	0.012
HEAT SINKS, circuit board mounting	6,700,000	3.850
INTEGRATORS, circuit board mounting	753	0.11
INVERTERS, dc-ac	270	0.090
INVERTERS, dc-dc	2,850	0.195
JACKS, JACK PANELS, PLUGS, assemblies	1,184	0.335
KNOBS, DIALS, for computer consoles	—	0.07
LAMINATES, printed circuit	3,000,000	6.50
LAMPS, photosensor	500,000	0.225
LAMPS, pushbutton set-type indicators	275,000	0.100
LAMPS, readout indicator	9,100,000	3.290
METERS, elapsed time recorders	20	0.10
MOTORS, servo	1500	0.2
MOTORS, stepping	6000	0.5
MOTORS, synchronous	2,000	0.2
MULTIPLEXERS, analog (up to 100 mv full scale; relay; random sampling)	90	0.455
MULTIPLEXERS, analog (up to 100 mv full scale; relay; sequential sampling)	240	0.86
MULTIPLEXERS, analog (up to 100 mv full scale; solid-state, random sampling)	500	0.500
MULTIPLEXERS, analog (up to 100 mv full scale; solid-state, sequential sampling)	600	0.250
MULTIPLEXERS, analog (over 100 mv full scale; relay; random sampling)	15	0.015
MULTIPLEXERS, analog (over 100 mv full scale; relay; sequential sampling)	25	0.025

Market Survey — Partial Results (13% return)

CALENDAR 1966

Product	No. of Units	\$ Volume (in millions)
MULTIPLEXERS, analog (over 100 mv full scale; solid-state; random sampling)	36	0.260
MULTIPLEXERS, analog (over 100 mv full scale; solid-state; sequential sampling)	—	—
MULTIPLEXER CONVERTER (single unit with multiplexer, sample and hold amplifier and A to D converter)	43	0.495
MULTIPLEXER, digital	116	0.76
NETWORKS, resistance	7,000	0.073
OSCILLATORS, voltage-controlled	1,200	0.25
PANELS, power distribution	—	—
POTENTIOMETERS, precision	133,400	1.91
POWER SUPPLIES, ac regulated	413	0.165
POWER SUPPLIES, ac unregulated	—	—
POWER SUPPLIES, dc regulated	21,600	3.080
POWER SUPPLIES, dc unregulated	1,363	0.193
RANDOM NUMBER GENERATORS	500	0.1
READOUTS AND DISPLAYS, numeric and alphanumeric (other than CRT)	2	0.30
RECTIFIERS, silicon-controlled	1500	0.00175
REGULATORS, current, ac	—	—
REGULATORS, current, dc	—	—
REGULATORS, frequency	150	0.025
REGULATORS, voltage, ac	—	—
REGULATORS, voltage, dc	200	0.020
RELAYS, dry reed	370,000	1.557
RELAYS, latching	135,000	0.562
RELAYS, mercury wetted reed	41,500	0.211
RELAYS, miniature and submin.	996,400	11.247
RELAYS, solid-state	—	—
RESISTORS (all types)	2,310,000	1.57
RFI GASKETS AND SHIELDING MATERIALS	—	—
SCANNERS, crossbar	—	—
SIGNAL CONDITIONERS	—	—
SOCKETS, IC mounting	—	—
SOCKETS, semicond. mounting	—	—
SOLENOID DRIVERS, solid-state	—	—
SOLENOIDS	190,000	3.75
SWITCHES, code bar	—	—
SWITCHES, illuminated pushbutton	5,000	0.050
SWITCHES, pushbutton	20,000	0.550
SWITCHES, rotary	10,000	0.080
SWITCHES, snap-action	—	—
SWITCHES, thumbwheel	602,500	3.018
SWITCHES, toggle	2,500	0.008
SYNCHROS-RESOLVERS	—	—
TEMPERATURE DETECTORS, alarms for fan-cooled computers and systems	—	—
TERMINAL BLOCKS, strips, boards	580,000	0.323
TERMINALS, feedthrough	1,033,000,000	4.2
TERMINALS, lugs	1,033,000,000	4.2

Product	No. of Units	\$ Volume (in millions)
TERMINALS, miniature	1,036,000,000	4.39
TIME CODE GENERATORS	100	0.06
TIMERS, interval	150	0.07
TRANSFORMERS, power	104,000	0.95
TRANSFORMERS, pulse	3,000	0.02
TRANSISTORS, field effect	—	—
TRANSISTORS, germanium	316,100	0.488
TRANSISTORS, silicon	—	—
6. EDUCATIONAL SYSTEMS AND TRAINING AIDS		
DIGITAL LOGIC DEMONSTRATORS AND BREADBOARD KITS	505	0.18
COMPUTERS, educational, analog	40	0.94
COMPUTERS, educational, digital	120	0.44
DISPLAYS, graphic panel, view-graphs (for computer training)	—	—
INSTRUCTIONAL SYSTEMS, computer-based (non-military)	78	0.52
KEYPUNCH TRAINING AIDS	—	—
7. FORMS, EDP SUPPLIES, AND ACCESSORIES		
AIR CONDITIONERS (for EDP rooms)	262	1.322
ANTI-STATIC SPRAYS, PAINTS, AND CHEMICALS	—	—
BINDERS (for EDP forms)	134,000	0.14
BOARDS, PROGRAMMING; plugboards and panels	1000	1.0
CABINETS, acoustical (for EDP equip.)	10	0.002
CABINETS, STORAGE RACKS (for magnetic tape reels)	1,250	0.120
CABINETS, STORAGE RACKS, CONTAINERS (for disk packs)	150	0.025
CANNISTERS, magnetic tape	10,000	0.006
CARDS, conventional punch	2,100,000,000	2.05
CARDS, edge punch	11,000,000	0.012
CARDS, magnetic	—	—
CHARTS, GRAPHIC DISPLAYS (for program production scheduling)	200	0.020
CLEANING MATERIALS AND EQUIP. (for magnetic tape)	503	0.614
CORRECTION SEALS, MICR documents	14,500,000	0.033
CORRECTION SEALS, punch card	10,000	0.001
CORRECTION SEALS, punch tape	—	—
COUNTER SCALES, punch card	—	—
DESKS, TABLES, AND STANDS (for calculators)	51,000	0.802
DESKS, TABLES, AND STANDS (for keypunch units)	17,200	0.283
DESKS, TABLES, AND STANDS (for programmers' stations)	20	0.005
DESKS, TABLES, AND STANDS (for typewriters)	9,706	0.252
ENVELOPES AND MAILERS, punch cards	—	—

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Product	No. of Units	\$ Volume (in millions)
ENVELOPES AND MAILERS, punch tape	—	—
ENVELOPES, continuous	10,919,393	0.23
ERASERS, bulk, magnetic tape	506	0.010
FIRE DETECTION/ALARM DEVICES (for EDP rooms)	—	—
FLOOR PLANNING AIDS (for EDP rooms)	1,000	Free
FLOORING (for EDP rooms)	750,580	3.70
FLOW CHART TEMPLATES, KITS, AND AIDS	—	—
FORMS, continuous, machine processed	185,000,000	4.05
FORMS HANDLING (bursters, deleavers, and defachers)	30	0.007
FORMS HANDLING, collators	—	—
FORMS HANDLING, decollators	3	0.003
FORMS HANDLING, document counters	—	—
FORMS HANDLING, label applicators	—	—
FORMS HANDLING, OCR source document	—	—
FORMS HANDLING, slitters	—	—
FORMS HANDLING, stackers	—	—
KEYPUNCH PERFORMANCE AIDS	—	—
LABELS, continuous, gummed (for machine applications)	600,000	0.0045
LABELS, continuous, pressure sensitive (for machine applic.)	204,500,000	1.685
MICROFILM APERTURE CARDS	5,000,000	0.100
PAPER (for line printers and keyboard printers)	—	15.925
PAPER (for MICR equip.)	—	2.230
PAPER (for OCR equip.)	—	0.300
PAPER (for recorders and plotters)	—	0.020
PAYMENT COUPON BOOKS, machine readable	—	—
PENCILS AND PENS, mark sensing	—	—
RECONDITIONERS, magnetic tape	20	0.650
RECONDITIONERS, punch card	—	—
REEL CLIPS AND BELTS, magnetic tape	—	—
REELS, magnetic tape	—	—
REELS, punch tape	534	0.010
RIBBONS, ink (for computer printers and tab equip.)	252,300	2.74
SAFES AND VAULTS (for EDP tapes and records)	—	—
SKEW METERS AND TESTERS, magnetic tape	—	—
SPLICERS, magnetic tape	400	0.020
SPLICERS, punch tape	175	0.013
TAGS (for EDP machine processing)	—	—
TAPE, magnetic	422,000	9.25
TAPE, punched (Mylar)	800	0.024
TAPE, punched (Mylar-coated foil)	—	—
TAPE, punched (paper)	1,090	0.375

Product	No. of Units	\$ Volume (in millions)
TAPE, punched (paper-coated alum.)	—	—
TAPE, punched (paper-coated Mylar)	—	—
TIME RECORDERS, machine usage	20	0.100
TRAYS, BINS, HOLDERS (for punch cards)	5,950	0.212
TRAYS, BINS, HOLDERS (for punch tape)	100	0.003
WINDERS, magnetic tape	20	0.050
WINDERS, punch tape	430	0.25
8. GRAPHIC DATA SYSTEMS AND DEVICES		
CRT CONSOLES, alphanumeric	—	—
CRT CONSOLES, alphanumeric with linear image	33	1.125
CRT CONSOLES, alphanumeric with linear image and optical projection	—	—
CRT FILM PROCESSORS	—	—
CRT SYMBOL GENERATORS	8	0.045
CURVE TRACERS-DIGITIZERS, automatic	—	—
CURVE TRACERS-DIGITIZERS, manual	145	1.450
FILM SCANNERS	10	0.065
HANDWRITING SYSTEMS, electronic	—	—
MICROFILM DATA RETRIEVAL SYSTEMS, computer-controlled	—	—
PLOTTERS, film exposing	—	—
PLOTTERS, moving pen, analog controller	50	0.050
PLOTTERS, moving pen, digital controller	4	0.25
PROJECTORS, optical, computer controlled slide selecting	130	0.235
STORAGE AND RETRIEVAL SYSTEMS, computer-controlled, image accessing and indexing	—	—
STORAGE AND RETRIEVAL SYSTEMS, computer-controlled, image accessing, indexing and processing	—	—
TYPE-SETTING SYSTEMS, computerized	240	3.9
9. MEDIA CONVERTERS		
CONVERTERS, document to magnetic tape	—	—
CONVERTERS, document to punched card	—	—
CONVERTERS, document to punched tape	—	—
CONVERTERS, magnetic tape to facsimile	—	—
CONVERTERS, magnetic tape to line printer	—	—
CONVERTERS, magnetic tape to magnetic tape	10	0.30
CONVERTERS, magnetic tape to punched card	—	—

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Product	No. of Units	\$ Volume (in millions)	Product	No. of Units	\$ Volume (in millions)
CONVERTERS, magnetic tape to punched tape	13	0.16			
CONVERTERS, punched card to magnetic tape	—	—			
CONVERTERS, punched card to punched tape	—	—			
CONVERTERS, punched tag to magnetic tape	—	—			
CONVERTERS, punched tag to punched card	—	—			
CONVERTERS, punched tape to line printer	—	—			
CONVERTERS, punched tape to magnetic tape	14	0.20			
CONVERTERS, punched tape to punched card	—	—			
CONVERTERS, punched tape to punched tape	20	0.13			
10. MEMORY SYSTEMS AND MAGNETIC RECORDERS					
CARD MEMORY SYSTEMS, magnetic	—	—			
CORE MEMORY SYSTEMS, coincident-current, magnetic	828	17.16			
CORES, PLANES, AND STACKS, ferrite memory (without electronics)	24,000	11.1			
DELAY LINE MEMORY SYSTEMS	5	0.02			
DISK MEMORY SYSTEMS, magnetic fixed head	211	3.082			
DISK MEMORY SYSTEMS, magnetic, movable head	55	6.700			
DRUM MEMORY SYSTEMS, magnetic	463	10.80			
FRAMES, MOUNTING (for memory cores)	50,000,000	0.050			
PLATED WIRE MEMORY PLANES AND STACKS	—	—			
PLATED WIRE MEMORY SYSTEMS	—	—			
RECORDING HEADS, magnetic disk	10,050	0.51			
RECORDING HEADS, magnetic drum	30,200	0.35			
RECORDING HEADS, magnetic tape	21,500	4.00			
SEARCH EQUIPMENT, magnetic tape	2	0.05			
SYNCHRONIZATION UNITS, magnetic drum and disk	10	0.09			
TAPE SYSTEMS, magnetic, analog	25	0.250			
TAPE SYSTEMS, magnetic, digital	926	5.45			
TAPE SYSTEMS, magnetic, incremental recorders	6	0.081			
TAPE SYSTEMS, magnetic, with keyboard input transcribers	—	—			
THIN-FILM MEMORY SYSTEMS	15	0.30			
11. PRINTERS					
PRINTER-KEYBOARDS	—	—			
PRINTERS, digital strip recording	447	0.342			
PRINTERS, line	141	3.401			
PRINTERS, non-impact	5	0.840			
12. PRODUCTION, ASSEMBLY AND TEST EQUIPMENT					
AMMETERS (all types)	80,050	1.030			
ANALYZERS, digital differential	—	—			
ANALYZERS, pulse height	200	0.2			
ANALYZERS, spectral	125	0.5			
ANALYZERS, waveform	49	0.315			
BENCHES, WORK STATIONS, electronic assembly	1,450	0.345			
BONDERS, thermal compression (for IC and thin-film production)	10	0.140			
BRIDGES, limit (all types)	—	—			
CABLE LACERS	—	—			
CAMERAS (for circuit production)	—	—			
CAMERAS, oscilloscope	—	—			
CAPACITANCE TESTERS	—	—			
CLEANING MACHINES, pc board	10	0.01			
COMPONENT COUNTING MACHINES	—	—			
COMPONENT LEAD BENDING AND FORMING MACHINES	—	—			
COMPONENT MARKERS	—	—			
COMPONENT SEQUENCING AND FEEDING MACHINES	750	2.00			
COMPONENT SORTING MACHINES	—	—			
CRIMPING MACHINES, wire	—	—			
CURRENT DIVIDERS	—	—			
CUTTERS, component lead	—	—			
CUTTERS, WIRE, automatic measuring	—	—			
DRAFTING TOOLS AND AIDS, pc layout	—	—			
DRILLS, pc board	—	—			
DRYING OVENS	12	0.13			
ENCAPSULATING AND PLOTTING MACHINES	252	4.55			
ETCHING MACHINES and TOOLS, pc	—	—			
EVAPORATORS, vacuum feedthroughs (for IC production)	38	0.40			
FREQUENCY COUNTERS	—	—			
GENERATORS, digital function	500	1.150			
HARNESS TESTERS, cable	149	3.66			
HARNESS TYING SYSTEMS	—	—			
INSERTION MACHINES, component	204	2.50			
INSERTION MACHINES, connector	—	—			
INSERTION MACHINES, eyelet	223	2.30			
INSERTION MACHINES, terminal	—	—			
INSULATION TESTERS	—	—			
MEMORY CORE TEST JIGS AND HANDLING MACHINES	20	0.05			
NULL DETECTORS	—	—			
OHMMETERS	35	0.030			
OSCILLATORS, audio test	—	—			
OSCILLOSCOPES	—	—			
PHASE METERS AND DETECTORS	—	—			
PHOTO AND DARK ROOM EQUIP. (for circuit production)	—	—			

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Product	No. of Units	\$ Volume (in millions)
PHOTORESIST STRIPPERS, chemical	—	—
POTENSIOMETERS, portable test	—	—
PRODUCTION MONITORING DEVICES (for IC production)	—	—
RFI TEST AND MEASURING EQUIPMENT	—	—
SAWS, pc board	—	—
SCRIBING EQUIP., IC	—	—
SOLDERING EQUIP. (for IC and thin-film assembly)	1015	0.225
SOLDER LEVELERS	—	—
SOLDERING MACHINES, dip	1,097	0.060
SOLDERING MACHINES, wave	229	1.050
STANDARDS, capacitance	—	—
STANDARDS, frequency	—	—
STANDARDS, inductance	—	—
STANDARDS, phase	—	—
STANDARDS, resistance	100	0.010
STANDARDS, time	—	—
STANDARDS, voltage, ac	—	—
STANDARDS, voltage, dc	—	—
SUBSTRATE PREPARATION EQUIP.	—	—
TESTERS, core memory exercisers	—	—
TESTERS, digital logic module	—	—
TESTERS, integrated circuit	3	0.150
TESTERS, semiconductor	123	0.065
TRAYS, BINS, RACKS, circuit board handling	—	—
VACUUM DEPOSITION EQUIP., IC and thin film	—	—
VOLTAGE DIVIDERS	—	—
VOLTMETERS, ac, dc, differential	70,110	2.005
VOLTMETERS, digital	20	0.040
WATTMETERS	—	—
WELDING EQUIP. (for IC and thin-film production)	350	0.500
WIRE MARKING MACHINES, BANDS AND TAGS	2,000	0.150
WIRE STRIPPING CHEMICALS (insulation stripper)	—	—
WIRE STRIPPING EQUIP.	—	—
WIRE WRAPPING MACHINES	—	—

Product	No. of Units	\$ Volume (in millions)
13. PUNCHED CARD EQUIPMENT		
ACCOUNTING MACHINES, card programmed	5	0.050
CARD PUNCHES, automatic (up to 100 cards per minute)	15	0.020
CARD PUNCHES, automatic (over 100 cards per minute)	—	—
CARD PUNCHES, edge-punching	2	0.002
CARD PUNCHES, portable	20	0.005
CARD READERS (up to 100 cards per min.)	—	0.005
CARD READERS (100 to 300 cards per min.)	—	0.0019
CARD READERS (over 300 cards per min.)	—	0.007
CARD READERS, edge-punched	—	—
CARD READERS, static	—	—
CARD READ-PUNCH UNITS	—	0.012
CARD REPRODUCERS, automatic	—	0.022
COLLATORS, punched card	10	0.020
PUNCHED TAG READERS	—	0.003
SORTERS, punched card	5,010	0.074
VERIFIERS, punched card	2	0.003
14. PUNCHED TAPE EQUIPMENT		
ACCOUNTING MACHINES, punched tape programmed	400	4.00
PRINTER-PUNCH UNITS, paper tape	5,523	6.045
PUNCHES, paper tape	2,867	1.931
READERS, paper tape	8,030	4.656
REPRODUCERS, automatic, paper tape	—	—
SPOOLERS, paper tape	2,083	1.211
15. TYPEWRITERS AND INPUT KEYBOARDS		
KEYBOARD ENCODERS, alphanumeric	2,819	0.20
KEYBOARD ENCODERS, numeric	—	0.07
KEYBOARD TELEPRINTERS	2,374	2.54
TYPEWRITERS, computer input-output	7,400	2.6

**COMPUTER-RELATED SERVICES
PORTION OF MARKET SURVEY
ON NEXT PAGE**

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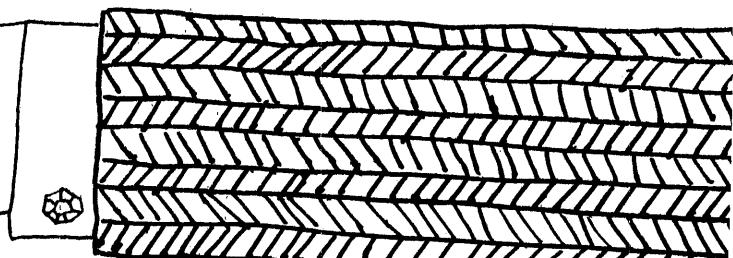
COMPUTER-RELATED SERVICES

Service	\$ Volume (in millions)
COMMERCIAL TIME SHARING SERVICES & INFORMATION UTILITIES	1.210
COMPUTERIZED DIRECT MAIL SERVICES & LIST MAINTENANCE	0.550
CONSULTING & ASSISTANCE COMPANIES (independent of mfgrs.); accounting business and commercial applications	7.032
CONSULTING & ASSISTANCE COMPANIES (independent of mfgrs.); real-time, one-line control, scientific applications	18.982
CONSULTING & ASSISTANCE COMPANIES (independent of mfgrs.); computer evaluations, selections, installation planning	4.017
CONSULTING & ASSISTANCE COMPANIES; advanced computer equipment design and feasibility studies	1.665
CONSULTING & ASSISTANCE COMPANIES; management information systems planning, operations research	8.314
CONSULTING & ASSISTANCE COMPANIES; computer product planning surveys, market research studies	1.921
CONSULTING & ASSISTANCE COMPANIES; (independent of mfgrs.); programming language development (e.g., assemblers, compilers, monitors, executives)	5.755

Service	\$ Volume (in millions)
INSURANCE, EDP casualty	—
LEASING, EDP equipment (other than mfgrs.)	9.010
MACHINE TIME RENTAL/PROCESSING SERVICES; analog or hybrid facilities	5.830
MACHINE TIME RENTAL/PROCESSING SERVICES; commercial EDP facilities, keypunching, processing	8.142
MACHINE TIME RENTAL/PROCESSING SERVICES; scientific digital computing facility	10.395
MAGNETIC TAPE RE-CONDITIONING/CERTIFICATION SERVICE	0.350
PERSONNEL RECRUITMENT & PLACEMENT	—
PERSONNEL, TEMPORARY; keypunchers, programmers, operators, maintenance technicians	0.88
RECORDS CONVERSION, miscellaneous documents to unit records	1.00
SEARCHING SERVICE, retrieval of particularized data via computer	0.002
TRAINING INSTITUTES, COMMERCIAL; computer courses, seminars, correspondence courses	0.705
USED EQUIPMENT BUYING, SELLING, LEASING	0.08

*See Product Directory
of Names and Addresses
of Manufacturers of
Products covered in this
Market Survey*

*See Service Directory
of Names and Addresses
of Companies Offering
Computer-Related Services*



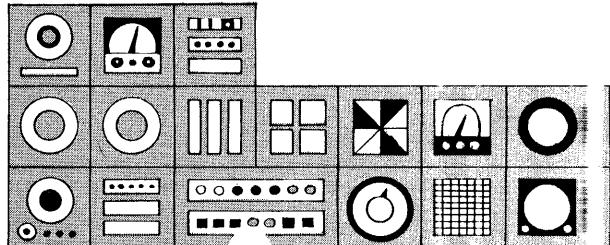
Equipment Characteristics Review

Characteristics, comparisons and specifying guidelines for computers, peripheral equipment and major components are presented in this section. The specific products included are:

GENERAL PURPOSE DIGITAL COMPUTERS	page 38
GENERAL PURPOSE ANALOG AND HYBRID COMPUTERS	page 69
DATA COMMUNICATIONS TERMINALS AND SPECIAL PROCESSORS	page 76
GRAPHIC DATA SYSTEMS AND DEVICES	page 94
EDP FORMS TECHNOLOGY	page 112
EXTERNAL STORAGE SYSTEMS	page 126
DIGITAL MAGNETIC TAPE SYSTEMS	page 131
COMPUTER PRINTERS	page 136
PUNCHED CARD EQUIPMENT	page 140
PUNCHED TAPE EQUIPMENT	page 143
INPUT TYPEWRITERS AND KEYBOARDS ..	page 153
INTERNAL MEMORY SYSTEMS	page 154
LOGIC CIRCUITS AND MODULES	page 165

Over 1000 product catalogues and reference manuals from nearly 300 companies were reviewed by the editorial staff in preparing this section. From this volume of material was extracted the data and specifications considered most important for purchasing decisions. Following each product review are product summary charts which provide tabular comparisons of all the products discussed. Although the publisher does not guarantee the accuracy of the product specifications, they are believed to be reliable. Any product specification errors or omissions could be due to inadequate data supplied by the manufacturer or misinterpretation of manufacturers' published catalogues.

The material in this section will be updated in subsequent issues of COMPUTER INDUSTRY ANNUAL and in the quarterly updating supplements. The combination of products selected for review in this issue are considered to be most representative of the needs of potential users. This does not imply that products not included in this section are less important to the computer industry. We are already looking ahead to next year when this section will not only be updated but expanded to include more products, more components, and more user application information. We invite reader comments regarding the product reviews in this issue and we welcome suggestions for other product reviews to be included in subsequent issues.



GENERAL-PURPOSE DIGITAL COMPUTERS

At the present time, there are approximately 110 different models of general-purpose digital computers on the market. Purchase prices range from \$6,000 to \$10,000,000. The corresponding monthly rentals range from \$200 to \$300,000. As of January 1, 1967, about 40,000 computers were installed and nearly 20,000 machines were on order.

The specific applications of this vast and varied array of computers are too numerous to mention. And, mere listing of applications would serve no real purpose since the computer professional is already familiar with current and potential uses of computers, and the layman is certainly aware of the computer's impact in such diverse fields as banking, insurance, transportation, communications, education, and medicine. It is important, however, to recognize the three fundamental areas of application. These are:

1. Business data processing;
2. General computation;
3. Real-time, on-line control.

Traditionally, computers have been broadly classified as commercial or scientific. The scientific class of machines includes small computers typically used for some form of on-line control, and larger computers usually used for general computation. Most machines on the market are easily identified as either commercial or scientific. However, it is becoming more difficult to distinguish between commercial and scientific computers, particularly in view of the speed and data formats of the new, third generation machines.

Regardless of the application, all general-purpose digital computers exhibit the same fundamental architecture which consists of five basic sections: input, control, memory, arithmetic, and output. Beyond this elementary comparison, computer mainframes differ substantially. The design of the five basic sections varies significantly from one machine to another in order to accommodate the special processing and/or computing requirements of specific applications. In the earlier days of the computer industry, the user had to be satisfied with letting the existing equipment dictate the solution to his particular problems. Today, the user is less restricted in his systems analysis and problem solutions because of the wider variety of central processors, peripherals, and software. However, selecting the most suitable equipment requires more evaluation and scrutiny than ever before.

To assist prospective computer users, this section includes a software review followed by product summary charts of all general-purpose digital computers currently being produced. The charts, which follow this section, include the major features of the machines listed in Tables 1, 2, and 3.

As previously mentioned, some of the newer machines operate comfortably in commercial as well as scientific environments because of their internal speeds, data manipulation techniques, and software capabilities. Therefore, it may be somewhat arbitrary to classify as scientific, computers such

as the GE 600 Series, CDC 3000 and 6000 Series, the Univac 400 Series, and the larger models of the IBM System 360.

COMPUTER SERVICES FLOURISH

It has become increasingly apparent in the last few years that the art of computer usage is proceeding at a much slower pace than that of computer design. The reasons for this condition are many and varied; however, the two most important reasons are:

1. Insufficient number of experienced computer users;
2. Accelerated computer sales have required manufacturers to devote more emphasis to manufacturing than to applications.

It cannot be said that manufacturers are totally preoccupied with hardware design and production. Considerable progress is being made in documenting successful applications, exploiting new applications, improving the efficiency of existing computer facilities, and training prospective computer users. However, the computer manufacturers cannot handle this burdensome task alone. As evidence, consider the rapidly growing number of computer consulting and assistance companies. These companies provide a broad range of highly specialized services, including systems analysis, software development, personnel training and staffing, equipment leasing, EDP casualty insurance, equipment maintenance, used equipment brokering, and many other services. (See Directory of Services for a detailed list of computer-related services.) Computer-oriented consulting firms vary widely in size, specialties, and geographical areas of operation. Software development companies represent the largest (by dollar sales volume) segment of the computer-related service companies. Some software firms employ several hundred people and operate internationally. Some smaller firms only service local customers. There are software suppliers which not only develop programming languages for computer manufacturers but they also perform highly specialized systems analysis, applications programming, and installation planning for prospective computer customers. Some of the most widely known software suppliers include:

Adams Associates
Auerbach Corporation
CEIR, Inc.
Computer Applications, Inc.
Computer Sciences Corporation
Computer Usage Corporation
Information Development Company
Planning Research Corporation
URS Corporation
Wolf Research Corporation

EQUIPMENT CHARACTERISTICS REVIEW

There are many other firms which concentrate on developing software for particular industries or for specific applications such as banking, insurance, payroll, information retrieval, inventory control, communications, process control, etc.; however, the firms listed above design programming languages and develop software for most types of applications for both commercial as well as scientific users.

It has been estimated that for each dollar spent on computer hardware, another dollar is spent for systems analysis, programming, software development, and related services. Furthermore, it is estimated that within the next ten years, software and related services will cost 2 dollars for each dollar worth of hardware. This, of course, is another way of saying that the service end of the computer industry will account for nearly 70 percent of the industry's total revenues.

SOFTWARE REVIEW

There are many factors for a potential buyer to consider when selecting a computer or data processing system. The major areas requiring considerable evaluation and scrutiny on the part of the buyer includes hardware, software, and after-delivery services available from the manufacturer. As computer users know, there is no simple, cook-book approach for selecting a computer configuration to satisfy a particular application. Hardware and software capabilities of the available computer models must be closely compared. Quantitative tabulations and comparisons of computer hardware are usually easier to prepare and are more straightforward than comparisons of the corresponding software. For this reason, this text is devoted primarily to a discussion of current programming languages, operating systems, and standard routines. This, of course, does not imply that hardware merits less attention than software during procurement evaluations. Tabular comparisons of all current computer models are provided in the product summary charts following this text.

Programming Costs Escalate

The rapid technological advances of the last decade have resulted in dramatic improvements in the speed and reliability of computing equipment. Also, hardware costs have been reduced substantially due to design improvements and higher production volumes. At the same time, many sophisticated devices and techniques have been added to the system designer's arsenal: random access devices of several varieties, communications adapters to allow computers to "talk" to each other, interactive display devices, mainframe features such as memory barricades to permit time-sharing and multi-programming, etc. All of these advances tend to give the user considerably more computing power for his dollar. Unfortunately, however, these advances have also caused an escalation in the cost and complexity of programming. Even though it is advantageous for a systems designer to be able to select hardware uniquely suited to his particular needs, an attendant reduction in programming costs cannot be assumed. Irrespective of hardware configuration and capability, any plans for new computer facilities still

must include careful consideration of the availability of experienced programming personnel.

More so now than in the past, software has become an integral part of many hardware lines in order to minimize programming complexity. By selecting the correct combination of hardware and software required for a particular application, the user can minimize costs and have a working installation in the shortest possible time. In effect, users are being relieved somewhat of tedious programming chores through the availability of new programming aids, improved languages, and more extensive applications programs. This trend is, of course, not completely new. Even with the earliest machines, attempts were made to relieve programmers from the clerical drudgery involved in machine coding. Utility programs and subroutine libraries were available to avoid repetitive coding of similar tasks. But hardware was so expensive compared to programming, and hardware was often so slow in an absolute sense, that great pains had to be taken to optimize coding to get the last millisecond of efficiency into a routine. Under these circumstances, it was necessary for a programmer to have complete access to all features of the hardware. In many areas of computer application this situation still holds true, notably in systems programming for real-time, on-line control systems. In most areas, however, the outlook has changed dramatically. With the relation between hardware costs and programming costs as it is today, it frequently makes sense to get a machine with more core storage than to have programmers stretching and straining to fit programs into the smaller machine. It also is sensible to use higher level programming languages, which are less efficient in use of storage and processor time, rather than spend an undue amount of effort in programming with a lower level language and possibly missing installation deadlines.

In light of the growing importance of software, and its multiplying complexity, the following text attempts to review and classify the important software systems available with current computer hardware.

Machine Language Coding

While all internal operations of a computer are initiated by machine recognizable instructions, it is quite rare today for any user to write a program in machine language. The chief use of actual machine language is in the debugging stages when a programmer is attempting to locate possible programming errors and inserts a small routine directly into the machine to "patch" his program on the spot. This can be extremely useful in certain machines and is a useful tool to an experienced programmer. However, even this practice is being replaced somewhat by symbolic debugging software as we shall discuss below. Some small machines are programmed with plugboards and this form of programming can be considered actual machine language. To program these machines, the user must become very familiar with each machine function as represented by a hub on the control panel and he must translate the problem to a series of steps which can be programmed. While this is a comparatively laborious task, it must be realized that the machines which use this system are small ones

EQUIPMENT CHARACTERISTICS REVIEW

and the total number of instructions in a program is never excessively large. This means that the total effort is not too great and such small machines can be used effectively. This type of programming is also favored in some circumstances because it eases the transition between tabulating equipment, which also uses plugboards, and the larger stored-program machines.

Assembly Language Programming

Probably the most widely-used programming language in use today is assembly language. In this form, a programmer has complete access to all machine facilities and yet he is relieved of most of the essentially clerical tasks of keeping track of storage locations of data and instructions. The programmer also writes instructions in a symbolic form which has more significance to him than a string of numbers. Assembly languages have, generally, three types of statements: imperative statements, processor control statements, and declarative statements. Imperative statements are those which the machine translates into actual machine instructions and executes them at object time. Processor control statements are not machine instructions; instead, they signal the language processor of certain events such as "end", which might signify the end of the source program. All assembly languages also have facilities for declarative statements which define the sizes of data fields, and the relationships between data fields, symbolic names, and program constants.

Each assembly defines a set of mnemonic operation codes which will be translated to actual numeric machine codes before the program is executed. The purpose of such names is to make it easier to identify each program step when written on coding forms or printed by line printers, etc. It is simpler to remember that "MPY" means multiply than the machine language "14" or "#" and so forth. Mnemonic names also allow the language processor to accept pseudo-instructions such as declaratives and processor control statements in the same format as machine instructions. Assemblers also make provisions for data or constant fields to be called by symbolic names. These names are translated to actual memory locations in the assembly process. This frees the programmer from the necessity of keeping track of previous memory assignments of data or constants. In fact, the programmer need not worry about actual memory location except in unusual cases. By the use of declarative statements, the programmer can outline the characteristics of his data and let the assembly program handle memory allocations. An extension of the concept of symbolic addressing is relative addressing. With this feature, unnamed data or instructions may be referred to by their position relative to some named reference point or datum, such as "GROSS & 3". This reduces the need for naming every referenced datum and also enhances the readability of most programs.

Many assembly languages extend the power of the programmer by providing more sophisticated features. The most widely-available feature is the "macro" instruction. A macro instruction is coded by the programmer very much like any other imperative statement. Its purpose, however, is not to generate a single machine language instruction but to

perform a higher level task which takes several instructions. These are generated by the assembly program. A READ macro, for instance, may be expanded by the language processor into many instructions concerned with reading a tape, checking for errors, and recognizing end-of-reel conditions. This facility further reduces the programmer's concern for details and allows him to concentrate more on the logic of his problem. Macro instruction capability is usually accompanied by library facilities. The routines called for by the macro will be found in the library and included in the program. Many of the routines in the library are supplied with the assembly system, but most libraries are also able to accept routines written by the user for use at his particular installation. This feature enables a user to avoid repetitious coding of the same procedures for inclusion in many programs. He need only write them once, insert them in the library and subsequently call them with macro instructions in programs where needed.

Conditional assembly and tailoring of statements by inclusion of call parameters greatly extends the power of a macro system. When a call is made for the routine it is tailored according to values of parameters in the call statement.

Some assemblers allow the use of combinations of symbolic names to construct operands. Expressions thus constructed can make it easier for the programmer to express relations between data in a logical way and to have the assembler do the detailed analysis of address assignments.

Cobol

COBOL (Common Business Oriented Language) is a major procedure-oriented language developed for business applications. It has evolved through the efforts of computer manufacturers, the Department of Defense, and other organizations. The first version of COBOL to be widely implemented was COBOL '61 which was published by CODASYL (Conference on Data Systems Languages) in 1961. Work continued on the language and in 1963 COBOL '61 Extended was issued. The latest version is COBOL, Edition 1965 which has improved the language in order to take advantage of recent hardware developments. In COBOL'61, certain portions of the language were designated as "required" and others as "elective". As initially defined, if a language did not include at least the required features it was not COBOL. The elective features were included at the option of the implementor. In the 1965 Edition terms "required" and "elective" have been dropped.

COBOL is designed to be a machine-independent language. That is, its syntax and vocabulary are not dependent upon the peculiarities of any particular hardware but reflect instead the logic commonly encountered in business data processing. The language is not concerned with words, channels, index registers or accumulators, but the files, records, constants, and the logical and arithmetic relationships between the input and the output of a program. The statements of a COBOL program must be eventually reduced to machine language instructions before the job can be run, but this is done by the implementor's compiler. It is here that concern with capabilities of hardware is concentrated. In short, the compiler is translating the source language to machine language relieves the programmer of

EQUIPMENT CHARACTERISTICS REVIEW

the need to become intimately familiar with the operation of the hardware. This is a major benefit of COBOL and of other procedure-oriented languages. The source program written in this high-level language also follows more closely the logic of the business problem, whereas an assembly language program is forced to follow machine logic much more closely. This means that a COBOL program is more easily understood by other people and can be followed to some extent by someone with a minimum of training. Because of its English-like appearance, COBOL is self documenting to a much greater extent than machine-oriented programs.

A major complaint of users is that the COBOL language does not use the hardware as efficiently as an experienced programmer would using an assembly language. More storage is used and running time is longer. The programmer is so removed from hardware logic that he may do things in a very uneconomic way. These objections have been valid in the past but to some extent are being remedied as new compilers are written with the experience of past errors in mind. Other shortcomings are more or less inherent in the nature of the language. An excessive amount of writing is required when coding in COBOL. The shorthand methods of other languages are not generally available and the programmer is forced to write, have keypunched, and verify lengthy data structures, verbs, and names. Compilation times are relatively high because of the extensive analysis required to decode and translate a very flexible language with many variations. These drawbacks, however, are greatly outweighed by the advantages of the language, and COBOL is becoming an increasingly important and valuable language.

While COBOL is designed as a standard language, several versions of it have been published, as mentioned above. Further diversity has occurred in the implementation by manufacturers of "required" or "elective" sets or by the addition of special features particularly suited to one machine or to one type of data processing problem. In writing COBOL programs which are intended to run on different computers, examination should be made for differences between compilers which are available for the machines in question. To minimize program conversion efforts, programs written for this situation should be designed to use only those features of the language which are common to all implementations. The American Standards Association has developed a standard for COBOL language which again makes a distinction between the extent of implementations. The ASA Standard defines the "Minimum ASA Standard COBOL" and the "Full ASA Standard COBOL". If a particular implementation supplies the minimum level of each "Functional Processing Module" (as defined by the ASA Standard) it is Minimum ASA COBOL. The Full ASA COBOL implements the maximum level of each "Functional Processing Module". Additional elements may be added to a language which are not specified in the Standard without rendering the compiler non-standard.

Some differences between Minimum and Full Standard COBOL are enumerated below. These are not intended to be an exhaustive analysis but rather an indication of the kinds of differences between the full language and its subset.

1. Names of data fields in the full COBOL may be qualified, e.g. NUMBER OF PART, while in the minimum set, names must be unique and not qualified.
2. The COMPUTE verb is not implemented in the minimum set.
3. The CORRESPONDING option is not implemented in the minimum set.
4. REDEFINES clauses may be nested in the full language but not in the minimum set.
5. READ INTO is part of the full language only.

The above list is certainly not inclusive, but the potential user should recognize, from the few examples, that a considerable difference can be found between compilers. These differences would substantially influence the ease and speed of coding, flexibility, preciseness of the resulting program, and value of the program when documented. The user should take these factors into consideration and not assume that "COBOL is COBOL".

Fortran

FORTRAN (FORmula TRANslator) is a procedure-oriented language developed for use in scientific problem solving. The first widely-used version was called FORTRAN II. While this is still in use even on late model computers, a more recent version, FORTRAN IV, is now available. The American Standards Association has published a standard FORTRAN IV. FORTRAN is the most widely-used procedure oriented language at this time. This language has the advantages associated with other procedure-oriented languages, i.e.; the programmer need not be overly familiar with the hardware characteristics; a source program follows problem and not machine logic; the program is largely self-documenting and can be followed easily; and problems can be coded much faster than with assembly language coding.

FORTRAN is largely machine independent but because of a lack of standardization in its early development, some adjustments are necessary to move from one computer to another. The language consists of several types of source statements which generally fall into such categories as arithmetic control, input/output, specification, and subprogram control. Various rules govern the composition of expressions, the layout of data in memory, the number system employed, and other features. These rules vary from one implementation to another, which means that source statements must be expressed slightly differently for the different dialects of the language. Among the many dialects of FORTRAN, certain basic concepts remain constant but the exact manner in which they are implemented may be quite different. Also, the rules and restrictions on the use of certain parts of the language may be different. Several of the areas where differences are usually found are as follows.

1. In the construction of expressions, many implementations require that all variables be of the same type; i.e., real, complex, integer, etc. Other versions allow for mixed expressions.

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2. The number of dimensions allowed in an array vary from one version to another. In some cases only two are allowed, in others three, and in others there is no limit.

3. The method of expressing subscripts can be very restrictive in some compilers and very permissive in others. As an example, some compilers allow subscripts to be subscripted themselves, while others do not.

4. While the early implementations of FORTRAN had no provision for overlapping input/output instructions with internal operations, later versions frequently have this ability.

5. Some of the latest versions of FORTRAN are able to operate in conversational mode. This means that they accept one statement at a time, perform some grammar and syntax checks, and immediately notify the programmer of any errors. When the entire program has been entered correctly, the rest of the compilation takes place. The programmer can then direct the system to execute the program. This mode is useful for direct communication between an on-line programmer and the computer in a high-level language.

This is necessarily an abbreviated list of differences among FORTRAN's. The user should realize that significant variations do exist, and that these will influence the speed and ease with which programs can be written.

Report Generators

Report generators, generally considered as languages, are collections of pre-written routines designed to allow rapid writing of relatively uncomplicated programs in problem-oriented terms. These systems provide the ability to perform common data processing functions requiring a relatively large amount of handling and a limited amount of logic and calculation. Each report generator specifies its own "language" and there has been no attempt to standardize. Some of these generators are interpretive in that no object program is produced. Some report generators are languages, in the sense that they have operation codes and operands, and others use control cards which the user completes in a prescribed manner. The common feature is that report generators are designed to do simple jobs with a minimum of training or effort on the user's part.

PL/1

PL/1 is a new language designed for use on both data processing and scientific problems, as well as for real-time and systems programming. It incorporates features found to be useful in previous languages such as COBOL, FORTRAN, and ALGOL and takes into account new hardware features such as mass stores and data communications interfaces. It tries to incorporate techniques to allow

for all possibilities in the mixed group of applications at which it is aimed. Few PL/1 compilers are available yet and user experience is extremely limited.

Other Procedure Oriented Languages

ALGOL (Algorithmic Language) is a rigidly defined language used to describe computational processes in a manner which facilitates translation to machine code. The basic element in describing calculations is the arithmetic expression. Expressions are compounded by means of operators into formulae called assignment statements. Other language elements are provided to control alternatives, loops, and other problem logic. In addition, the attributes of variables are defined by declaratives. These basic elements have functions similar to corresponding elements in other languages. The difference is in the structure and power of ALGOL statements.

JOVIAL is a procedure-oriented language based on ALGOL. It is particularly suited to "command and control" or other applications in which a large, real-time processing program must be written.

A few other specialized procedure-oriented languages include LISP, BALGOL, and SIMSCRIPT. These languages, along with several other similar types, have been implemented for special applications.

Utility Programs

Most software systems include a variety of programs which perform miscellaneous day-to-day functions. Some of these programs offer only minor conveniences, while some are essential to daily operations. This assortment of routines is sometimes referred to, collectively, as utility or service routines.

The most common utility routines are generated sort/merge programs. A sort is a program which rearranges records stored on tape or other auxiliary storage into some desired order based on key fields in the record. A merge takes several previously-ordered files and combines them into a single-ordered file. Usually, sort/merge programs are supplied to the user in very general form along with routines which assist in adapting the basic routines to satisfy particular requirements of the user. For this reason they are called "generated" programs.

Another form of utility routine is the linkage editor which combines several segments of coding into one routine. The use of such a system allows the repeated use of subroutines in many different applications.

Debugging and program test routines are forms of utility programs which aid the programmer in finding programming errors and ensuring that programs operate under worst-case conditions. These routines are written in such a way that the programmer can "patch" his program as he discovers errors. This allows him to make several tests before he is forced to reassemble the program. In several such systems the programmer is allowed to make patches using the same mnemonics and symbolic names he used in the original coding. The most frequently-used utility programs are the type which facilitate routine data handling. These include inquiries to auxiliary storage devices, tape copying and editing, and media conversions such as card-to-tape, tape-to-card, tape-to-print, etc.

Input/Output Routines

Since almost every program uses the input/output facilities of the computer, many software systems have evolved with standardized subroutines that perform these tasks. This leads to standardized handling of data and error conditions and guarantees compatibility when more than one programmer works on a system. It also saves a considerable amount of programming time since each coder does not have to solve the problem individually. Standardized input/output routines vary from very simple read and write programs to elaborate systems of file control with object time device assignment. Some basic input/output routines may handle only magnetic tapes while more elaborate routines may process tapes, unit records, mass storage, disc files, display devices, and communications channels. Generally, such elaborate systems operate under control of an operating system as previously discussed. The simpler input/output routines operate as part of the assembly processor and are usually confined to magnetic tape and unit record devices. By means of instructions such as OPEN, GLOSE, GET, and PUT the programmer is able to accomplish all his input/output operations on logical records. All translation from logical to physical terms and all error detection and correction is done by the standardized subroutines.

Operating Systems

To the user of a data processing system, a significant measure of performance is the internal operating speed of a machine. This feature tells the user how fast a particular job can be processed once a run has started. This does not take into account, however, such variables as setup time and delays while awaiting operator instructions. As machine speeds have increased, such "overhead" operations have taken on an increasingly important segment of time. To counteract the degradation of system performance by manual intervention, operating systems have come into wider use. The general purpose of these systems is to automate, as much as possible, manual procedures and, at the same time, to provide a standard and helpful machine environment for the programmer, installation manager, and machine operator. This environment is intended to relieve programmers and managers of many details not essential to their functions.

Most operating systems have three major tasks; language translation, job control, and data control. Operating systems can accept properly identified programs in several languages and call on the proper translator to reduce the statements to some form of machine language. Generally, a translator working under control of an operating system will produce machine code in standard format regardless of the source language. This module will be in relocatable form. That is, actual machine addresses will not be specified and it can be combined with other modules of code as specified by the programmer. This technique of putting together several pieces to make a program is highly efficient as it maximizes the use that can be made of various routines previously coded. Once programs are reduced to this standard format, the source language is immaterial. Thus, for example, a bond yield program written in FORTRAN can be combined with a check writing

program written in COBOL to achieve a combination of the best features of each language. In some operating systems, libraries of user routines are maintained and complete facilities for updating are available. In other systems, program modules must be loaded into the system in the appropriate sequence in order to be properly linked. While this affects the efficiency of the linking process, it does no change the nature of the advantages to be gained.

In the early data processing systems, it was the practice for the operator to load one program into the machine, set up any special equipment that was needed, have the computer execute the program, remove the results, and then get ready for the next run. It soon became apparent that while the operator was mounting tapes or getting a program deck from a card file, the computer was idle. Such idle time was frequently a large portion of available time. In order to minimize this loss of efficiency, monitor programs are now available which automatically load programs into the computer from auxiliary storage devices such as tapes or discs. In this way, a minimum of time is lost in job-to-job transition and, because of the decrease in human intervention, operator errors are minimized. With monitor systems, a large amount of operator responsibility is relieved, and any mistakes the programmer may make can be corrected and recorded in the form of cards so that subsequent use of the program will be successful.

The increase in flexibility afforded the programmer by an effective operating system is also a factor in operational efficiency. With a job-to-job transition automatically provided, the programmer can decide the next processing step based on object time conditions and cause the appropriate program to be called. Previously, this would have necessitated elaborate operating instructions and constant operator action. In a similar way, a program which is too lengthy to fit in the computer's memory can be constructed as a series of overlays which can be transferred in and out of the machine as needed.

An operating system provides a uniform language and procedure for communicating with the computer operator. Since all programs operate under its control, they use its facilities to inform the operator of program status. This means that whenever a program in the installation requires that a tape be mounted, for instance, the operator will get the same message. Without an operating system, each programmer might make up his own message, frequently causing operator confusion and delay.

This standard operating environment also helps the programmer. He does not have to decide when each new program overlay is needed. Also, operating standards are maintained with a minimum of programmer indoctrination and supervision.

Some of the more advanced operating systems include multi-program features which provide significant time saving advantages. With this capability, two or more tasks can be processed concurrently. Control may be assigned exclusively to one task or another depending upon priorities. The method of deciding when to shift control varies from one system to another and is often different from job to job within one system. For instance, one task may retain control until it requests an input/output operation. At that point, the other task will take over, while the first would be stalled. This method can be made more elaborate by adding the addi-

TABLE 1
BUSINESS DATA PROCESSORS

MANUFACTURER	MODEL
Burroughs Corporation	B-100, B-250, B-263, B-273, B-283, B-300, B-2500, B-3500, B-5500, B-8500
General Electric	115, 235, 415, 425, 435
Honeywell EDP Div.	400, 800, 1400, 1800, 200/120, 200/200, 200/1200, 200/4200, 200/8200
IBM Corporation	1401, 1410, 1460, 7010, System 360 — Models 20, 30, 40, 44, and 50
National Cash Register	390, 500, 315, 315-100, 315 RMC
Radio Corp. of America	3301, Spectra 70 — Models 15, 25, 35, 45 and 55
Sperry Rand Univac Div.	9200, 9300, 1004 I, 1004 II, 1004 III, 1005 I, 1005 II, 1005 III, 1050 III

TABLE 2
MEDIUM AND LARGE SCIENTIFIC MACHINES

MANUFACTURER	MODEL
Control Data Corp.	3100, 3300, 3800, 6400, 6600
Digital Equipment Corp.	PDP-10
Electronic Associates	EAI-8400
EMR Computer Division	6020, 6040, 6050, 6070
General Electric	625, 635, 645
IBM Corporation	1130, 7040, 7044, 7094, System 360 — Models 65, 67, 75 and 90
Raytheon Computer Div.	520
Scientific Control Corp.	SCC-6700
Scientific Data Systems	940, 9300, Sigma 5, Sigma 7
Sperry Rand Univac Div.	418, 491, 492, 494, 1108 II

tional condition that regardless of other conditions, no task may retain control for more than some set period of time. When the period is over, control automatically passes to the next task. In order to maximize the usefulness of such a scheme, the programmer must be relieved of the responsibility of ensuring that tasks proceeding together do not interfere with each other. This responsibility must be assigned to the operating system.

Multi-programming increases the throughput capability of the computer by utilizing, more fully, the resources available. When one task cannot use the central processor because it is waiting for a card read operation, for instance, the other task takes over. If one program does not use the printer, for example, it can be run with another program which does use the printer. This implies that idle time is minimized. The operating system assumes the responsibility of determining tasks sequences so that effective use can be made of all components of the system. In some small, research-oriented systems, an operating system is used not for the sake of efficiency, but to improve the method of communication between user and machine. Such systems allow a researcher to communicate with the computer in a simplified manner. The operating system then translates these shorthand instructions into program calls and parameter lists and causes the appropriate action to be taken. When the results are observed, the user decides on his next course of action and again instructs the operating system. This interaction continues until all paths have been tried. Thus, an effective operating system, coupled with a library of generalized subprograms, is almost essential to an interactive data processing environment.

Some operating systems provide complete facil-

ties for handling various types of data sets. Others provide only partial facilities and in still other schemes, data control facilities are built into language translators rather than into the operating system. A potential user should determine which of these schemes to use in his proposed installation and whether this is the best method for his purposes. The goal of complete data management facilities in an operating system is to eliminate the need for programmer attention to the characteristics of the data storage and data organization, and to allow him to concentrate on the logical properties of the data. In order to accomplish this, the designer of the software devises several standard forms of data organization and access methods. The programmer selects that method which is best suited to his application and uses pseudo-instructions which perform logical operations upon the data set. Some of the functions this type of software offers are:

1. Control of the physical movement of data between central storage and auxiliary storage or external data sets;
2. Detection and correction of errors associated with data transfer;
3. Data buffering, blocking and deblocking, overlapping data operations with computing, and data set label processing;
4. Dynamic scheduling of input/output devices;
5. Logical handling of data sets without reference to physical characteristics of the storage devices; thus, data sets stored on discs, cards, tape, or other media can be handled similarly and independently of device type.

EQUIPMENT CHARACTERISTICS REVIEW

Operating systems have become increasingly complex and increasingly versatile in order to help

users take full advantage of the advanced facilities of their hardware. A good operating system can be a very effective means of multiplying programmer productivity, standardizing machine operations, increasing system throughput, and reducing the chances of undetected errors. A price must be paid for these advantages, however. Operating systems occupy storage space; in the case of advanced systems, the storage used can be sizable. Frequently, a larger machine will be needed to accommodate the operating system. These alternatives present trade-off decisions which must be made by the prospective user.

TABLE 3
SMALL-SCALE
SCIENTIFIC/CONTROL COMPUTERS

MANUFACTURER	MODEL
Business Information Technology	BIT-480
Control Data Corp.	CDC-1700
Data Machines, Inc.	DATA/620A
Digital Equipment Corp.	PDP-7, PDP-8/S, PDP-8, PDP-9
Electronic Associates, Inc.	EAI-640
EMR Computer Division	Advance 6130
General Electric Company	GE/PAC-4020, GE/PAC-4040, GE/PAC-4050 II, GE/PAC-4060
Honeywell, Inc. Computer Control Div.	DDP-124, DDP-416, DDP-516
Interdata	Interdata Model 3
IBM	IBM-1800
Interstate Electronics Corp.	IEC-1010
Logic Corp.	LC-1000
Scientific Control Corp.	SCC-650-2, SCC-655, SCC-660, SCC-670
Scientific Data Systems	Sigma 2
Systems Engineering Labs., Inc.	SEL-810A, SEL-840A

PRODUCT SUMMARY CHARTS

The accompanying charts summarize, in tabular form, the major features of the general-purpose digital computers which are currently available. For the key to manufacturer's model numbers, the reader is referred back to Tables 1, 2, and 3 in this section. As previously indicated, the charts classify each computer by its major area of application. The three classifications are:

1. Business data processors;
2. Medium and large scientific machines;
3. Small-scale scientific/control computers.

Since it is meaningless to compare small control computers with business data processors and large scientific computers, a different set of specification parameters is used for the small-scale machines.

The business data processors, as well as the medium and large scientific machines, are arranged in ascending order by price. This arrangement is believed to be advantageous for prospective users who wish to compare machines in the same price range. The small-scale control computers, on the other hand, are arranged alphabetically, by the manufacturer, since the basic mainframes are all in the same general price range. It should also be noted that purchase prices, rather than rental prices, are given for the small control computers, since the other hand, are arranged alphabetically, by manufacturer, since the basic mainframes are all in the same general price range. It should also be noted that purchase prices, rather than rental prices, are given for the small control computers, since the vast majority of them are purchased out-right rather than rented.

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors

Models listed in ascending order by monthly lease price

	NCR-390	UNIVAC-9200	NCR-500	UNIVAC 1004 I	UNIVAC 1005 I
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	1.1	1.2	1.3	1.5	1.5
Lease Price Range/Month (\$ Thousands)	0.9 to 1.9	1 to 3	0.76 to 2.5	1.1 to 1.9	1.4 to 2
DATE OF 1ST INSTALLATION	5/61	5/67	10/65	9/63	2/66
CENTRAL PROCESSOR					
Memory	Cycle time	107 usec.	1.2 usec.	22.5 usec.	8.0 usec.
	Number of words	200	8 to 16K	400	961
Word length	Bits/char	4	8	4 Numeric, 8 Alpha	6
	Bits/word	48	32	24	—
Number Base		Decimal	—	Decimal	Decimal
Execution Speed, Fixed Point	Add (full word)	11 msec.	104 usec.	99 msec.	224 usec.
	Multiply (full word)	77 msec. (min.)	—	125 msec.	—
	Divide (full word)	121 msec. (min.)	—	190 msec.	—
Index Registers	Number	0	8	3	0
	Hardware or memory loc.	N/A	Hardware	Memory	N/A
Indirect Addressing (yes, no)	No	No	No	No	Yes
Floating Point Hardware	None	X	X	X	X
	Standard	—	—	—	—
	Optional	—	—	—	—
Number of Instructions	20	35	50	20	40
Addresses/Instructions	3	2	3	1	1
Interrupt Control	No. of interrupt lines	0	1	0	0
	No. of interrupt registers	0	0	0	0
Special Features	Also available: Optical reader, mag. ledger	Thin-film memory	Also available optical reader, mag. ledger		
COMMUNICATION CONTROLS					
Max. No. of Terminals	—	—	—	1	1
Min. Data Rate (bits/sec)	—	—	—	2KC	2KC
Max. Data Rate (bits/sec)	—	—	—	40.8KC	40.8KC
Buffer size (bits)	—	—	—	None	None
Full Duplex (yes, no)	—	—	—	No	No
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	None	—	None	None
	Tape Speed (KC)	N/A	—	N/A	N/A
Punched Cards	Read Speed (cards/min.)	100	400/1000	100	400
	Punch Speed (cards/min.)	100	75	100	200
Paper Tape	Punch Speed (char/sec)	30	None	120	None
	Read Speed (char/sec)	650	None	650	None
Line Printer	No. of columns	132	96	96	132
	Speed (lines/min.)	120	250	125	400
Disc Storage	Capacity (char)	None	None	None	None
	Access Time (msec)	N/A	N/A	N/A	N/A
Magnetic Cards	Capacity (char)	None	None	None	None
	Access Time (msec)	N/A	N/A	N/A	N/A
Inter-active Displays	Numeric (yes, no)	No	No	No	No
	Alphanumeric (yes, no)	No	No	No	No
	Line Drawing (yes, no)	No	No	No	No
	Keyboard (yes, no)	No	No	No	No
	Light Pen (yes, no)	No	No	No	No
Console Typewriter (yes, no)	Yes	No	Yes	No	No

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	UNIVAC 1004 II	UNIVAC 1005 II	GE-115	UNIVAC 1005 III	IBM-360/20
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	1.6	1.6	1.8	2.1	2.2
Lease Price Range/Month (\$ Thousands)	1.3 to 2	1.6 to 2.9	1.3 to 4.8	1.6 to 2.9	1.2 to 3.6
DATE OF 1ST INSTALLATION					
	6/64	2/66	4/66	4/66	4/66
CENTRAL PROCESSOR					
Memory	Cycle time	6.5 usec.	6.5 usec.	6.5 usec/char	6.5 usec.
	Number of words	961 to 1922	2 to 4K	4 to 16K (char)	2 to 4K
Word length	Bits/char	6	6	8	6
	Bits/word	—	—	8	—
Number Base		Decimal	Decimal	—	Decimal
					Binary
Execution Speed, Fixed Point	Add (full word)	130 usec.	130 usec.	148 usec.	130 usec.
	Multiply (full word)	3.8 msec.	—	Subroutine	—
	Divide (full word)	—	—	Subroutine	—
Index Registers	Number	0	—	1	—
	Hardware or memory loc.	N/A	—	Hardware	—
Indirect Addressing (yes, no)	No	Yes	No	Yes	No
Floating Point Hardware	None	X	X	X	X
	Standard	—	—	—	—
	Optional	—	—	—	—
Number of Instructions	20	40	30	40	—
Addresses/Instructions	1	1	1 or 2	1	—
Interrupt Control	No. of interrupt lines	0	0	0	—
	No. of interrupt registers	0	0	0	—
Special Features					Byte manipulation
COMMUNICATION CONTROLS					
Max. No. of Terminals	1	1	1	1	—
Min. Data Rate (bits/sec)	2KC	2KC	110	2KC	—
Max. Data Rate (bits/sec)	40.8KC	40.8KC	2.4KC	40.8KC	—
Buffer Size (bits)	None	None	24	None	—
Full Duplex (yes, no)	No	No	Yes	No	—
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	None	None	None	200/800
	Tape Speed (KC)	N/A	N/A	N/A	8 to 34KC
Punched Cards	Read Speed (cards/min.)	615/2000	615	300/600	615
	Punch Speed (cards/min.)	200	200	100/300	200
Paper Tape	Punch Speed (char/sec)	None	110	60	110
	Read Speed (char/sec)	N/A	400	400	400
Line Printer	No. of columns	132	132	104/120/136	132
	Speed (lines/min.)	600	600	300/600	600
Disc Storage	Capacity (char)	None	None	None	7.25 million
	Access Time (msec)	N/A	N/A	N/A	97
Magnetic Cards	Capacity (char)	None	None	None	None
	Access Time (msec)	N/A	N/A	N/A	N/A
Inter-active Displays	Numeric (yes, no)	No	No	No	No
	Alphanumeric (yes, no)	No	No	No	No
	Line Drawing (yes, no)	No	No	No	No
	Keyboard (yes, no)	No	No	No	No
	Light Pen (yes, no)	No	No	No	No
Console Typewriter (yes, no)	No	No	No	No	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	UNIVAC 1004 III	NCR-315-100	UNIVAC 9300	S-200/120	SPECTRA 70/15
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	2.4	2.6	2.6	3.0	3.2
Lease Price Range/Month (\$ Thousands)	1.3 to 2.8	2.5 to 20	1.6 to 10	1.6 to 4.5	1.5 to 6.5
DATE OF 1ST INSTALLATION					
	6/64	5/63	10/67	2/66	10/65
CENTRAL PROCESSOR					
Memory	Cycle time	6.5 usec.	6 usec.	600 nsec.	3.0 usec.
	Number of words	961 to 1922	10 to 80K	8 to 32K	2 to 32K (char.)
Word length	Bits/char	6	4 Numeric, 6 Alpha	8	6 data bits
	Bits/word	—	12	32	—
Number Base		Decimal	Decimal	—	Binary/Decimal
Execution Speed, Fixed Point	Add (full word)	130 usec.	42 usec.	52 usec.	69 usec.
	Multiply (full word)	3.7 msec.	97 usec.	—	—
	Divide (full word)	—	222 usec.	—	—
Index Registers	Number	0	32	8	Up to 6
	Hardware or memory loc.	N/A	Memory	Hardware	Memory
Indirect Addressing (yes, no)	No	Yes	No	Yes	No
Floating Point Hardware	None	X	X	X	X
	Standard	—	—	—	—
	Optional	—	—	—	—
Number of Instructions	20	142	35	39	25
Addresses/Instructions	1	1	2	0, 1, or 2	2
Interrupt Control	No. of interrupt lines	0	5	1	1/control unit
	No. of interrupt registers	0	1	0	1
Special Features		Also available: Optical reader, MICR reader-sorter	Thin-film memory	Char. includes 6 data bits, 2 punctuation bits, 1 parity bit	
COMMUNICATION CONTROLS					
Max. No. of Terminals	1	—	—	Optional	1
Min. Data Rate (bits/sec)	2KC	—	—	45	2KC
Max. Data Rate (bits/sec)	40.8KC	—	—	30.6KC	2.4KC
Buffer Size (bits)	0	—	—	2 Char.	—
Full Duplex (yes, no)	No	—	—	Yes	No
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	50 to 250	200/556/800	800	200/556/800
	Tape Speed (KC)	5 to 25	12 to 120	34KC	7.2 to 96KC
Punched Cards	Read Speed (cards/min.)	615 to 2000	.360/2000	600/1000	300/800
	Punch Speed (cards/min.)	200	100/360	75/200	50 to 400
Paper Tape	Punch Speed (char/sec)	110	110	—	120
	Read Speed (char/sec)	400	600/1000	—	600
Line Printer	No. of columns	132	96/120/132	120	96/108/120/132
	Speed (lines/min.)	600	620/1000	600	450/1300
Disc Storage	Capacity (char)	None	None	—	Up to 1.2 billion
	Access Time (msec)	N/A	N/A	—	7.25 million
Magnetic Cards	Capacity (char)	None	5.5 to 16 million	None	249 million
	Access Time (msec)	N/A	235	N/A	385
Inter-active Displays	Numeric (yes, no)	No	Special	No	Yes
	Alphanumeric (yes, no)	No	Special	No	Yes
	Line Drawing (yes, no)	No	Special	No	No
	Keyboard (yes, no)	No	Special	No	Yes
	Light Pen (yes, no)	No	Special	No	No
Console Typewriter (yes, no)	No	Yes	No	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	B-250	B-100	B-2500	B-263	SPECTRA 70/25
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	4.2	4.3	5.0	5.1	5.2
Lease Price Range/Month (\$ Thousands)	2.8 to 6.7	1.9 to 6.2	4.2 to 12.3	—	4 to 12
DATE OF 1ST INSTALLATION					
	9/61	4/64	5/67	1/64	1/66
CENTRAL PROCESSOR					
Memory	Cycle time	10 usec.	10 usec.	2.0 usec.	6 usec.
	Number of words	400	400	5 to 30K	800
Word length	Bits/char	8	8	8	8
	Bits/word	12 char.	12 char.	16	12 char.
Number Base		12	12	10	12
Execution Speed, Fixed Point	Add (full word)	1.6 msec.	1.6 msec.	56 usec.	0.9 msec.
	Multiply (full word)	30.9 msec.	30.9 msec.	304 usec.	18.5 msec.
	Divide (full word)	7.2 msec.	7.2 msec.	440 usec.	4.3 msec.
Index Registers	Number	None	None	3 per program	None
	Hardware or memory loc.	N/A	N/A	Memory	N/A
Indirect Addressing (yes, no)		No	No	Yes	No
Floating Point Hardware	None	X	X	—	X
	Standard	—	—	—	—
	Optional	—	—	X	—
Number of Instructions		25	30	44	49
Addresses/Instructions		3	3	1, 2 or 3	3
Interrupt Control	No. of interrupt lines	—	—	—	1
	No. of interrupt registers	—	—	—	0
Special Features	Execution speed is for 4 digit operations				
COMMUNICATION CONTROLS					
Max. No. of Terminals	—	—	Optional	—	1
Min. Data Rate (bits/sec)	—	—	110	—	6
Max. Data Rate (bits/sec)	—	—	2400	—	48KC
Buffer Size (bits)	—	—	None	—	—
Full Duplex (yes, no)	—	—	No	—	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	—	200/556	200/556/800/1600	—
	Tape Speed (KC)	—	20/50	9 to 144KC	—
Punched Cards	Read Speed (cards/min.)	200/475/800	200/475/800	200/800/1400	200/475/800
	Punch Speed (cards/min.)	100/300	100/300	100/300	100/300
Paper Tape	Punch Speed (char/sec)	—	100	100	100
	Read Speed (char/sec)	—	500/1000	500/1000	500/1000
Line Printer	No. of columns	120/132	120/132	120/132	132/160
	Speed (lines/min.)	475/700/815/1040	475/700/815/1040	700/815/1040	475/700/815/1040
Disc Storage	Capacity (char)	—	—	—	7.25 Million
	Access Time (msec)	—	—	—	97.5
Magnetic Cards	Capacity (char)	—	—	None	—
	Access Time (msec)	—	—	N/A	—
Inter-active Displays	Numeric (yes, no)	No	No	No	Yes
	Alphanumeric (yes, no)	No	No	Yes	Yes
	Line Drawing (yes, no)	No	No	No	No
	Keyboard (yes, no)	Yes	Yes	Yes	Yes
	Light Pen (yes, no)	No	No	No	No
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	UNIVAC 1050 III	S-200/200	IBM-1401	SPECTRA 70/35	B-273
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	5.4	6.0	6.5	6.9	7.1
Lease Price Range/Month (\$ Thousands)	2.4 to 14	3 to 10	2 to 12	5.6 to 19	—
DATE OF 1ST INSTALLATION	9/63	7/64	10/60	10/66	1/64
CENTRAL PROCESSOR					
Memory	Cycle time	4.5 usec.	2.0 usec.	11.5 usec.	1.44 usec.
	Number of words	4 to .32K	2 to 65K char.	4 to 16K	16 to 65K
Word length	Bits/char	6	6 data bits	6	8
	Bits/word	—	—	—	32
Number Base	—	Binary/Decimal	Decimal	—	—
Execution Speed, Fixed Point	Add (full word)	117	48 usec.	700 usec.	22 usec. 0.9 msec.
	Multiply (full word)	—	419 usec.	1.1 msec.	110 usec. 18.5 msec.
	Divide (full word)	—	219 usec.	2.1 msec.	288 usec. 4.3 msec.
Index Registers	Number	7	Up to 15	3	16
	Hardware or memory loc.	Hardware	Memory	Memory	Memory
Indirect Addressing (yes, no)	No	Yes	No	No	No
Floating Point	None	X	X	X	— X
Hardware	Standard	—	—	—	X —
	Optional	—	—	—	—
Number of Instructions	—	41	—	144	49
Addresses/Instructions	—	0, 1 or 2	Variable	2	3
Interrupt Control	No. of interrupt lines	None	1/Control unit	None	3 None
	No. of interrupt registers	None	1	None	9 None
Special Features	Char. includes 6 data bits, 2 punctuation bits, 1 parity bit			16 words of non-addressable scratch pad	
COMMUNICATION CONTROLS					
Max. No. of Terminals	—	Optional	None	176	15
Min. Data Rate (bits/sec)	—	45	—	6	1KC
Max. Data Rate (bits/sec)	—	30.6KC	—	48KC	2.4KC
Buffer Size (bytes)	—	2 char.	—	—	2688
Full Duplex (yes, no)	—	Yes	—	Yes	No
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	200/1000	200/556/800	None	200/800 200/556/800
	Tape Speed (KC)	18 to 132KC	7.2 to 96KC	N/A	7.5 to 120 18 to 72
Punched Cards	Read Speed (cards/min.)	600/900	300/800	450	1435 200/475/800/1400
	Punch Speed (cards/min.)	200/300	50 to 400	250	100/300 100/300
Paper Tape	Punch Speed (char/sec)	110	120	—	100 100
	Read Speed (char/sec)	300/1000	600	—	200 500/1000
Line Printer	No. of columns	132	96/108/120/132	100/132	132/160 120/132
	Speed (lines/min.)	922	450 to 1300	465	625/1250 475/700/1040
Disc Storage	Capacity (char)	None	Up to 1.2 billion	—	7.25 million 480 million
	Access Time (msec)	N/A	—	—	97.5 20
Magnetic Cards	Capacity (char)	None	None	None	249 million None
	Access Time (msec)	N/A	N/A	N/A	385 N/A
Inter-active Displays	Numeric (yes, no)	No	Yes	No	Yes No
	Alphanumeric (yes, no)	No	Yes	No	Yes No
	Line Drawing (yes, no)	No	No	No	No No
	Keyboard (yes, no)	No	Yes	No	Yes No
	Light Pen (yes, no)	No	No	No	No No
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	B-283	B-3500	GE-415	B-300	NCR-315
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	7.1	7.2	7.6	8.4	8.5
Lease Price Range/Month (\$ Thousands)	—	4.8 to 20	4.8 to 13.5	4.8 to 14.2	3.8 to 30
DATE OF 1ST INSTALLATION					
	1/64	6/67	5/64	7/65	5/62
CENTRAL PROCESSOR					
Memory	Cycle time	6 usec.	1.0 usec.	5.8 usec.	6 usec.
	Number of words	800	5 to 250K	8 to 32K	8 to 1600
Word length	Bits/char	8	8	6	8
	Bits/word	12 char.	16	24	12 char.
Number Base	—	Decimal	—	—	Decimal
Execution Speed, Fixed Point	Add (full word)	0.9 msec.	28 usec.	17.8 usec.	0.9 msec.
	Multiply (full word)	18.5 msec.	152 usec.	65.6 usec.	18.5 msec.
	Divide (full word)	4.3 msec.	220 usec.	124.4 (min.)	4.3 msec.
Index Registers	Number	None	3 per program	1/4 of mem. size	None
	Hardware or memory loc.	N/A	Memory	Memory	N/A
Indirect Addressing (yes, no)	No	Yes	Yes	No	Yes
Floating Point Hardware	None	X	—	—	X
	Standard	—	—	—	—
	Optional	—	X	X	—
Number of Instructions	43	44	200	75	142
Addresses/Instructions	3	1, 2 or 3	1 or 2	3	1
Interrupt Control	No. of interrupt lines	None	—	1	None
	No. of interrupt registers	None	—	1	N/A
Special Features	Execution speed is for 4 digit operations			Each terminal line can service up to 128 consoles	
COMMUNICATION CONTROLS					
Max. No. of Terminals	15	Optional	6	15	100 lines
Min. Data Rate (bits/sec)	1KC	110	110	1KC	70
Max. Data Rate (bits/sec)	2.4KC	2.4KC	50KC	2.4KC	40.8KC
Buffer Size (bits)	2688	None	12	2688	Main memory
Full Duplex (yes, no)	No	No	Yes	No	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	200/556/800	200/556/800/1600	200/556/800	200/556/800
	Tape Speed (KC)	18 to 72	9 to 144	7.5 to 160	18 to 72
Punched Cards	Read Speed (cards/min.)	200/475/800/1400	200/800/1400	900	200/475/800/1400
	Punch Speed (cards/min.)	100/300	100/300	100/300	100/300
Paper Tape	Punch Speed (char/sec)	100	100	150	100
	Read Speed (char/sec)	500/1000	500/1000	500	500/1000
Line Printer	No. of columns	120/132	120/132	136	120/132
	Speed (lines/min.)	475/700/1040	700/815/1040	1200	475/700/1040
Disc Storage	Capacity (char)	480 million	100 million	94 million	480 million
	Access Time (msec)	20	60	199	20
Magnetic Cards	Capacity (char)	None	None	224 million	None
	Access Time (msec)	N/A	N/A	375	N/A
Inter-active Displays	Numeric (yes, no)	No	No	No	Special
	Alphanumeric (yes, no)	No	Yes	No	Special
	Line Drawing (yes, no)	No	No	No	Special
	Keyboard (yes, no)	No	Yes	No	Special
	Light Pen (yes, no)	No	No	No	Special
Console Typewriter (yes, no)	Yes	Yes	No	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	H-400	IBM 360/30	GE-425	S-200/1200	NCR-315-RMC
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	9.0	9.3	9.6	9.7	9.78
Lease Price Range/Month (\$ Thousands)	6 to 14	2.7 to 20,000	6 to 20	—	6 to 50
DATE OF 1ST INSTALLATION	12/61	6/65	6/64	1/66	9/65
CENTRAL PROCESSOR					
Memory	Cycle time	9.25 usec.	1.5 usec	3.9 usec.	1.5 usec.
	Number of words	1 to 4K	8 to 65K	8 to 32K	16 to 131K char.
Word length	Bits/char	6	8	6	6 Alpha, 4 Numeric
	Bits/word	48	—	24	2 Alpha, 3 Numeric
Number Base		Decimal/Binary	Binary	—	Decimal/Binary
Execution Speed, Fixed Point	Add (full word)	111 usec.	39 usec.	12 usec.	35 usec.
	Multiply (full word)	1319 usec.	313 usec.	46.6 usec.	304 usec.
	Divide (full word)	1795 usec.	560 usec.	93.5 (min.)	164 usec.
Index Registers	Number	3	16	1/4 of Mem. size	15 or 30
	Hardware or memory loc.	Memory	Memory	Memory	Memory
Indirect Addressing (yes, no)	Yes	No	Yes	Yes	Yes
Floating Point Hardware	None	X	—	—	—
	Standard	—	—	—	—
	Optional	—	X	X	X
Number of Instructions	63	—	200	41 or 55	184
Addresses/Instructions	3	2	1 or 2	0, 1 or 2	1 or 2
Interrupt Control	No. of interrupt lines	3	—	1	1/Control unit
	No. of interrupt registers	None	—	1	1 or 2
Special Features	MPY, DIV are optional	Memory protect available		Char. includes 6 data bits, 2 punctuation bits, 1 parity bit	MICR reader-sorter, optical reader also available. Thin-film rod memory
COMMUNICATION CONTROLS					
Max. No. of Terminals	Variable	—	6	Variable	100 lines
Min. Data Rate (bits/sec)	45	—	110	45	70
Max. Data Rate (bits/sec)	2KC	—	50KC	2.4KC	40.8KC
Buffer Size (bits)	512 char.	—	12	2 char.	Main memory
Full Duplex (yes, no)	No	—	Yes	Yes	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	400/556	800/1600	200/556/800	200/556/800
	Tape Speed (KC)	32 to 88.8	30 to 340	7.5 to 160	7.2 to 96
Punched Cards	Read Speed (cards/min.)	250	1000	900	300/800
	Punch Speed (cards/min.)	800	400	100/300	50/400
Paper Tape	Punch Speed (char/sec)	110	—	150	120
	Read Speed (char/sec)	1000	1000	500	600
Line Printer	No. of columns	120	120/132	136	96/108/120/132
	Speed (lines/min.)	600/900	200/1100	1200	450 to 1300
Disc Storage	Capacity (char)	None	7.25 million	94 million	Up to 1.2 million
	Access Time (msec)	N/A	97	199	—
Magnetic Cards	Capacity (char)	None	400 million	224 million	None
	Access Time (msec)	N/A	350	375	N/A
Inter-active Displays	Numeric (yes, no)	No	Yes	No	Yes
	Alphanumeric (yes, no)	No	Yes	No	Yes
	Line Drawing (yes, no)	No	Yes	No	Special
	Keyboard (yes, no)	No	Yes	No	Special
	Light Pen (yes, no)	No	Yes	No	Special
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	GE-235	IBM-1460	SPECTRA 70/45	IBM-360/44	RCA-3301
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	10.9	10.9	11.5	12	12
Lease Price Range/Month (\$ Thousands)	6 to 28	3.5 to 16	7.5 to 26	5 to 25	10 to 39
DATE OF 1ST INSTALLATION	4/64	10/63	7/66	12/66	7/64
CENTRAL PROCESSOR					
Memory	Cycle time	6 usec.	6 usec.	1.44 usec.	1.0 usec.
	Number of words	4 to 16K	8 to 16K	16 to 32K	32 to 131K
Word length	Bits/char	6	6	8	—
	Bits/word	20 + Parity	—	32	32
Number Base	—	Decimal	Binary	Binary	Decimal
Execution Speed, Fixed Point	Add (full word)	12	108 usec.	5 usec.	1.75 usec.
	Multiply (full word)	30 to 138 usec.	—	66 usec.	—
	Divide (full word)	154 to 176 usec.	—	91 usec.	—
Index Registers	Number	3 to 96	3	16	16
	Hardware or memory loc.	Hardware	Hardware	Scratchpad	Hardware
Indirect Addressing (yes, no)	Yes	Yes	No	No	Yes
Floating Point Hardware	None	—	X	—	—
	Standard	—	—	X	X
	Optional	X	—	—	X
Number of Instructions	300	—	144	—	61
Addresses/Instructions	1	1	2	1	2
Interrupt Control	No. of interrupt lines	1	—	3	—
	No. of interrupt registers	1	—	9	—
Special Features	—	—	—	—	—
COMMUNICATION CONTROLS					
Max. No. of Terminals	15	None	240	—	160
Min. Data Rate (bits/sec)	60	N/A	6	—	200
Max. Data Rate (bits/sec)	2.4KC	N/A	48KC	—	48KC
Buffer Size (bits)	None	N/A	—	—	100 char.
Full Duplex (yes, no)	Yes	N/A	Yes	—	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	200/556/800	200/800	200/800	200/800
	Tape Speed (KC)	15/42/60	7.2 to 90	7.5 to 120	30 to 340
Punched Cards	Read Speed (cards/min.)	400/1000	800	1435	615
	Punch Speed (cards/min.)	100/300	250	100/300	200
Paper Tape	Punch Speed (char/sec)	110	150	100	110
	Read Speed (char/sec)	250/1000	500	200	20
Line Printer	No. of columns	120	120/132	132/160	120
	Speed (lines/min.)	450/900	600/1100	625/1250	600
Disc Storage	Capacity (char)	75 million	3 million	7.25 million	—
	Access Time (msec)	199	250	97.5	—
Magnetic Cards	Capacity (char)	None	None	249 million	—
	Access Time (msec)	N/A	N/A	385	—
Inter-active Displays	Numeric (yes, no)	No	No	Yes	Yes
	Alphanumeric (yes, no)	No	No	Yes	Yes
	Line Drawing (yes, no)	No	No	No	Yes
	Keyboard (yes, no)	No	No	Yes	Yes
	Light Pen (yes, no)	No	No	No	No
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS

Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	GE-435	H-1400	S-200/2200	IBM-1410	IBM-360/40
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	14	14	15	17	19.5
Lease Price Range/Month (\$ Thousands)	8 to 25	10 to 22	5 to 30	6 to 32	5 to 35
DATE OF 1ST INSTALLATION	9/65	12/63	12/65	12/61	5/65
CENTRAL PROCESSOR					
Memory	Cycle time	2.7 usec.	6.5 usec.	1.0 usec.	4.5 usec.
	Number of words	16 to 32K	4 to 32K	16 to 262K char.	10 to 80K
Word length	Bits/char	6	6	6	8
	Bits/word	24	48	—	—
Number Base	—	Binary/Decimal	Binary/Decimal	Decimal	Binary
Execution Speed, Fixed Point	Add (full word)	9 usec.	78 usec.	25 usec.	88 usec.
	Multiply (full word)	38.6 usec.	923 usec.	205 usec.	—
	Divide (full word)	80.9 (min.)	1183 usec.	134 usec.	—
Index Registers	Number	1/4 of mem. size	3	15 to 30	15
	Hardware or memory loc.	Memory	Memory	Memory	Memory
Indirect Addressing (yes, no)	Yes	Yes	Yes	No	No
Floating Point Hardware	None	—	—	X	—
	Standard	—	—	—	—
	Optional	X	X	X	X
Number of Instructions	200	72	41 or 55	—	—
Addresses/Instructions	1 or 2	3	0, 1 or 2	1	1
Interrupt Control	No. of interrupt lines	1	3	1/Control unit	—
	No. of interrupt registers	1	—	1 or 2	—
Special Features		Optional MYP/DIV Hardware	Char. includes 6 data bits, 2 punctuation bits, 1 parity bit		
COMMUNICATION CONTROLS					
Max. No. of Terminals	6	Variable	Variable	—	—
Min. Data Rate (bits/sec)	110	45	45	—	—
Max. Data Rate (bits/sec)	50KC	2KC	5.1KC	—	—
Buffer Size (bits)	12	512 char.	2 char.	—	—
Full Duplex (yes, no)	Yes	No	Yes	—	—
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	200/556/800	400/556	200/556/800	200/800
	Tape Speed (KC)	7.5 to 160	32 to 88.8	7.2 to 96	7.2 to 90
Punched Cards	Read Speed (cards/min.)	900	250	300/800	800
	Punch Speed (cards/min.)	100/300	800	50/400	250
Paper Tape	Punch Speed (char/sec)	150	110	120	—
	Read Speed (char/sec)	500	1000	600	500
Line Printer	No. of columns	136	120	96/108/120/132	120/132
	Speed (lines/min.)	1,200	600/900	450/1300	600/1100
Disc Storage	Capacity (char)	94 million	None	Up to 1.2 billion	234 million
	Access Time (msec)	199	N/A	—	180
Magnetic Cards	Capacity (char)	224 million	None	None	—
	Access Time (msec)	375	N/A	N/A	—
Inter-active Displays	Numeric (yes, no)	No	No	Yes	No
	Alphanumeric (yes, no)	No	No	Yes	No
	Line Drawing (yes, no)	No	No	No	No
	Keyboard (yes, no)	No	No	Yes	No
	Light Pen (yes, no)	No	No	No	No
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	H-800	S-200/4200	IBM-7010	SPECTRA 70/55	B-5500
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	22	25	26	27	28
Lease Price Range/Month (\$ Thousands)	19 to 35	—	12 to 35	16 to 62	16 to 160
DATE OF 1ST INSTALLATION	12/60	12/67	10/63	7/66	11/64
CENTRAL PROCESSOR					
Memory	Cycle time	6.0	750 nsec.	6 usec.	0.84 usec.
	Number of words	4 to 32K	65 to 524K char.	40 to 100K	65 to 524K
Word length	Bits/char	6	6	6	8
	Bits/word	48	24 data bits	—	32
Number Base		Binary/Decimal	Binary/Decimal	Decimal	Binary
Execution Speed, Fixed Point	Add (full word)	24 usec.	12 usec.	33 usec.	2 usec.
	Multiply (full word)	162 usec.	82 usec.	70 usec.	12 usec.
	Divide (full word)	384 usec.	56 usec.	110 usec.	19 usec.
Index Registers	Number	64	15 to 30	15	16
	Hardware or memory loc.	Hardware	Memory	Hardware	Scratchpad
Indirect Addressing (yes, no)	Yes	Yes	No	No	Yes
Floating Point Hardware	None	—	—	—	—
	Standard	—	—	X	X
	Optional	X	X	X	—
Number of Instructions	41 or 62	41 or 55	—	144	—
Addresses/Instructions	3	0, 1 or 2	1	2	1 or 0
Interrupt Control	No. of interrupt lines	—	1/Control unit	—	3
	No. of interrupt registers	—	1 or 2	—	9
Special Features	Multiprogramming up to 8 concurrent programs	Char. includes 6 data bits, 2 punctuation bits, 1 parity bit			
COMMUNICATION CONTROLS					
Max. No. of Terminals	Variable	Variable	—	240	15
Min. Data Rate (bits/sec)	6.0	45	—	6	44.5
Max. Data Rate (bits/sec)	1.2KC	5.1KC	—	48KC	2.4KC
Buffer Size (bits)	1 char.	2 char.	—	—	168 to 2688
Full Duplex (yes, no)	No	Yes	—	Yes	—
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	400/556	200/556/800	200/800	200/556/800
	Tape Speed (KC)	32 to 88.8	7.2 to 96	7.2 to 90	15 to 120
Punched Cards	Read Speed (cards/min.)	250	300/800	800	900/1470
	Punch Speed (cards/min.)	800	50/400	250	300
Paper Tape	Punch Speed (char/sec)	110	120	—	100
	Read Speed (char/sec)	1000	600	500	1000
Line Printer	No. of columns	120	96/108/120/132	120/132	120/160
	Speed (lines/min.)	600/900	450/1300	600/1100	1000
Disc Storage	Capacity (char)	None	Up to 1.2 billion	234 million	—
	Access Time (msec)	N/A	—	180	—
Magnetic Cards	Capacity (char)	None	None	—	None
	Access Time (msec)	N/A	N/A	—	N/A
Inter-active Displays	Numeric (yes, no)	No	Yes	No	Yes
	Alphanumeric (yes, no)	No	Yes	No	Yes
	Line Drawing (yes, no)	No	No	No	No
	Keyboard (yes, no)	No	Yes	No	Yes
	Light Pen (yes, no)	No	No	No	No
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Business Data Processors (Continued)

Models listed in ascending order by monthly lease price

	IBM-360/50	H-1800	S-200/8200	B-8500
MONTHLY RENTAL				
Typical Lease/Month (\$ Thousands)	33	35	36.6	150
Lease Price Range/Month (\$ Thousands)	14 to 55	27 to 60	33 to 80	80 to 300
DATE OF 1ST INSTALLATION				
	8/65	11/63	4/68	—
CENTRAL PROCESSOR				
Memory	Cycle time	2 usec.	2.0 usec.	750 nsec.
	Number of words	65 to 524K	8 to 65K	262 to 1,048K char.
Word length	Bits/char	8	6	6
	Bits/word	—	48	48 + parity
Number Base		Binary	Binary/Decimal	Binary/Decimal
Execution Speed, Fixed Point	Add (full word)	4 usec.	8.0 usec.	1.75 usec.
	Multiply (full word)	—	54 usec.	6 usec.
	Divide (full word)	—	40 usec.	14.25 usec.
Index Registers	Number	16	64	318
	Hardware or memory loc.	Hardware	Hardware	Memory/Hardware
Indirect Addressing (yes, no)	No	Yes	Yes	Yes
Floating Point Hardware	None	—	—	—
	Standard	X	—	—
	Optional	—	X	X
Number of Instructions	—	41 or 62	100 or 121	—
Addresses/Instructions	1	3	Up to 3	1
Interrupt Control	No. of interrupt lines	—	—	72
	No. of interrupt registers	—	—	1
Special Features		Multiprogramming, up to 8 concurrent programs	Multiprogramming, 2 processors (word + char.), up to 9 concurrent programs	Thin-film memory
COMMUNICATION CONTROLS				
Max. No. of Terminals	—	Variable	Variable	Unlimited
Min. Data Rate (bits/sec)	—	60	45	44.5
Max. Data Rate (bits/sec)	—	1.2KC	5.1KC	40.8KC
Buffer Size (bits)	—	1 char.	2 char.	—
Full Duplex (yes, no)	—	No	Yes	—
PERIPHERAL DEVICES				
Magnetic Tape	Density (bits/inch)	800/1600	400/556	200/556/800
	Tape Speed (KC)	30 to 340	32 to 88.8	7.2 to 96
Punched Cards	Read Speed (cards/min.)	1000	250	300/800
	Punch Speed (cards/min.)	400	800	50/400
Paper Tape	Punch Speed (char/sec)	—	110	120
	Read Speed (char/sec)	1000	1000	600
Line Printer	No. of columns	120/132	120	96/108/120/132
	Speed (lines/min.)	200	600/900	450/1300
Disc Storage	Capacity (char)	207 million	None	Up to 1.2 billion
	Access Time (msec)	75	N/A	—
Magnetic Cards	Capacity (char)	400 million	None	None
	Access Time (msec)	350	N/A	N/A
Interactive Displays	Numeric (yes, no)	Yes	No	Yes
	Alphanumeric (yes, no)	Yes	No	Yes
	Line Drawing (yes, no)	Yes	No	Yes
	Keyboard (yes, no)	Yes	No	Yes
	Light Pen (yes, no)	Yes	No	Yes
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines

Models listed in ascending order by monthly lease price

	IBM-1130	RAYTHEON-520	EMR-6020	SDS-9300	EMR-6040
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	1.6	3.2	4.3	4.9*	5.5
Lease Price Range/Month (\$ Thousands)	0.6 to 2	2.2 to 10	2.3 to 8	3 to 11	3.0 to 11.0
DATE OF 1ST INSTALLATION					
	9/65	10/65	1965	12/64	1966
CENTRAL PROCESSOR					
Memory	Cycle time	3.6 usec	1.0 usec	1.9 usec	1.75 usec
	Number of words	4 to 8 K	4 to 32 K	4 to 32 K	4 to 32 K
Word length	Bits/char.	8	6	6	6
	Bits/word	16	24 + parity	24	24
Number Base		Binary	Binary	Binary	Binary
Execution Speed, Fixed Point	Add (full word)	8 usec	1.0 usec	3.8 usec	3.8 usec
	Multiply (full word)	26 usec	6.5 usec	30.4 usec	8.75 usec
	Divide (full word)	76 usec	12.5 usec	—	17 usec
Index Registers	Number	3	7	3	3
	Hardware or memory loc.	memory	hardware	memory	hardware
Indirect Addressing (yes, no)	Yes	No	Yes	Yes	Yes
Floating Point Hardware	None	X	X	X	—
	Standard	—	—	—	—
	Optional	—	—	—	X
Number of Instructions	35	65	90	98	95
Addresses/Instructions	1	1	1	1	1
Interrupt Control	No. of interrupt lines	6	4 (standard)	64	1024
	No. of interrupt registers	1	4 (mem. loc.)	64 (mem. loc.)	—
Special Features	Byte manipulation, double precision available	Truncated MPY/DIV, 9 programmable registers	Double precision hardware available		Double precision Hardware available
COMMUNICATION CONTROLS					
Max. No. of Terminals	—	—	8 (channels)	40	8 (channels)
Min. Data Rate (bits/sec)	—	—	1.4 mc	60	1.4 mc.
Max. Data Rate (bits/sec)	—	—	10 mc	2.4 KC	10 mc
Buffer Size (bits)	—	—	24	8	24
Full Duplex (yes, no)	—	—	Yes	Yes	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	--	200/556/800	200/556/800	200/800
	Tape Speed (KC)	—	60	45/75/112	15/96
Punched Cards	Read Speed (cards/min.)	400	100/800	200/450/800/1400	200/800
	Punch Speed (cards/min.)	120	250	100/200	300
Paper Tape	Punch Speed (char/sec)	14.8	110	60/110	60
	Read Speed (char/sec)	14.8	300	300/500	300
Line Printer	No. of columns	120	80/160	120/132	120/132
	Speed (lines/min.)	82	300/1250	400/600/1000	140/1000
Disc Storage	Capacity (char)	1.2 million	2/2.98 million	50 million	67 million
	Access Time (msec)	55	20 to 185	20	up to 275
Magnetic Cards	Capacity (char)	—	None	None	None
	Access Time (msec)	—	N/A	N/A	N/A
Inter-active Displays	Numeric (yes, no)	—	Yes	Yes	Yes
	Alphanumeric (yes, no)	—	Yes	Yes	Yes
	Line Drawing (yes, no)	—	Yes	Yes	Yes
	Keyboard (yes, no)	—	Yes	Yes	No
	Light Pen (yes, no)	—	Yes	Yes	Yes
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

*4-year lease

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines (Continued)

Models listed in ascending order by monthly lease price

	SIGMA-5	EMR-6050	CDC-3100	PDP-10	UNIVAC 418
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	6.8	8.6	10	110 to 600**	10
Lease Price Range/Month (\$ Thousands)	2 to 20	3.5 to 14	3.5 to 16	110 to 600**	8 to 20
DATE OF 1ST INSTALLATION					
	12/67	1966	12/64	9/67	8/63
CENTRAL PROCESSOR					
Memory	Cycle time	850 nsec	1.9 usec	1.75 usec	1.0 usec
	Number of words	4 to 128 K	4 to 32 K	4 to 32 K	8 to 262 K
Word length	Bits/char	8	6	6	variable
	Bits/word	32	24	24	36
Number Base		Hexadecimal	Binary	Binary	—
Execution Speed, Fixed Point	Add (full word)	2.06 usec	3.8 usec	3.5 usec	2.1 usec
	Multiply (full word)	9.08 usec	5.7 usec	12.7 usec	9.1 usec
	Divide (full word)	15.45 usec	—	14.5 usec	12.0 usec
Index Registers	Number	7	3	3	15
	Hardware or memory loc.	Hardware	Hardware	Hardware	Optional
Indirect Addressing (yes, no)	Yes	Yes	Yes	Yes	No
Floating Point Hardware	None	—	—	—	X
	Standard	—	X	—	—
	Optional	X	—	X	—
Number of Instructions	89	110	164	365	99
Addresses/Instructions	1	1	1	1	1
Interrupt Control	No. of interrupt lines	224	64	32	7
	No. of interrupt registers	—	64 (mem. loc.)	5	128 (mem. loc.)
Special Features		Double precision hardware available		Any size byte manipulation, async. interleaved memory	
COMMUNICATION CONTROLS					
Max. No. of Terminals	200	8 (channels)	optional	64	256
Min. Data Rate (bits/sec)	60	1.4 mc	optional	50	50
Max. Data Rate (bits/sec)	120 KC	10 mc	6.6 mc	200 KC	40.8 KC
Buffer Size (bits)	8	24	32 K	—	8
Full Duplex (yes, no)	Yes	Yes	Yes	Yes	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	200/800	200/556/800	800	200/556/800
	Tape Speed (KC)	20/120	45/75/112	120	9 to 90
Punched Cards	Read Speed (cards/min.)	400/800	200/450/800/1400	1200	800
	Punch Speed (cards/min.)	300	100/200	252	100
Paper Tape	Punch Speed (char/sec)	10/150	60/110	350	50
	Read Speed (char/sec)	15/300	300/500	1000	300
Line Printer	No. of columns	132	120/132	136	132
	Speed (lines/min.)	600/1000	400/600/1000	1000	600
Disc Storage	Capacity (char)	0.75 to 24 million	50 million	200 million	2.6 million
	Access Time (msec)	up to 34	20	90	17.25 avg.
Magnetic Cards	Capacity (char)	None	None	400 million	None
	Access Time (msec)	N/A	N/A	400	N/A
Inter-active Displays	Numeric (yes, no)	Yes	Yes	Yes	No
	Alphanumeric (yes, no)	Yes	Yes	Yes	No
	Line Drawing (yes, no)	Yes	Yes	Yes	No
	Keyboard (yes, no)	Yes	Yes	Yes	No
	Light Pen (yes, no)	Yes	Yes	Yes	No
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

**Purchase price — No lease offered

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines (Continued)

Models listed in ascending order by monthly lease price

	EAI-8400	EMR-6070	SIGMA-7	SDS-940	CDC-3300
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	12	14.6	15*	18	19.5
Lease Price Range/Month (\$ Thousands)	6 to 22	5.5 to 26	5 to 30	4 to 25	7 to 26
DATE OF 1ST INSTALLATION					
	7/65	1966	12/66	4/66	9/65
CENTRAL PROCESSOR					
Memory	Cycle time	1.75 usec.	1.9 usec.	850 usec.	1.75 usec.
	Number of words	8 to 65K	4 to 32K	4 to 128K	65K
Word length	Bits/char	—	6	8	6
	Bits/word	36	24	32	24
Number Base		Binary	Binary	Hexadecimal	Octal
Execution Speed, Fixed Point	Add (full word)	5.28 usec.	3.8 usec.	2.6 usec.	3.5 usec.
	Multiply (full word)	8.06 usec.	5.7 usec.	4.9 usec.	7.0 usec.
	Divide (full word)	11.39 usec.	—	12.7 usec.	17.5 usec.
Index Registers	Number	7	3	7	1
	Hardware or memory loc.	Hardware	Hardware	Hardware	Hardware
Indirect Addressing (yes, no)	Yes	Yes	Yes	Yes	Yes
Floating Point Hardware	None	—	—	—	—
	Standard	X	—	—	—
	Optional	—	X	X	X
Number of Instructions		123	110	110	89
Addresses/Instructions		1	1	1	1
Interrupt Control	No. of interrupt lines	16 to 256	64	224	1024
	No. of interrupt registers	16 to 256	64 (mem. loc.)	—	—
Special Features		2 parity bits included in 36 bit word	Convolver, double precision hardware available		
COMMUNICATION CONTROLS					
Max. No. of Terminals	32	8 (channels)	200	40	Optional
Min. Data Rate (bits/sec)	—	1.4mc	60	60	Optional
Max. Data Rate (bits/sec)	400KC	10mc	120KC	2.4KC	10.8mc
Buffer Size (bits)	16	24	8	8	54K
Full Duplex (yes, no)	Yes	Yes	Yes	Yes	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	556 to 800	200/556/800	200/800	200/800
	Tape Speed (KC)	36 to 120KC	45/75/112	20/120	15/96
Punched Cards	Read Speed (cards/min.)	400/1400	200/450/800/1400	400/800	200/800
	Punch Speed (cards/min.)	100/300	100/200	300	300
Paper Tape	Punch Speed (char/sec)	110	60/110	10/150	60
	Read Speed (char/sec)	500	300/500	15/300	300
Line Printer	No. of columns	132	120/132	132	120/132
	Speed (lines/min.)	300/1000	400/600/1000	600/1000	140/1000
Disc Storage	Capacity (char)	7.25 million	50 million	0.75 to 24 million	67 million
	Access Time (msec)	85	20	Up to 34	Up to 275
Magnetic Cards	Capacity (char)	none	None	None	400 million
	Access Time (msec)	N/A	N/A	N/A	400
Inter-active Displays	Numeric (yes, no)	Yes	Yes	Yes	Yes
	Alphanumeric (yes, no)	Yes	Yes	Yes	Yes
	Line Drawing (yes, no)	Yes	Yes	Yes	Yes
	Keyboard (yes, no)	Yes	Yes	Yes	No
	Light Pen (yes, no)	Yes	Yes	Yes	Yes
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

*4-year lease

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines (Continued)

Models listed in ascending order by monthly lease price

	UNIVAC 491	IBM-7040	UNIVAC 492	SCC-6700	IBM-7044
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	22	25	25	30	36.5
Lease Price Range/Month (\$ Thousands)	13 to 65	9 to 40	16 to 70	20 to 35	20 to 60
DATE OF 1ST INSTALLATION					
	9/65	4/63	9/65	—	7/63
CENTRAL PROCESSOR					
Memory	Cycle time	4.8 usec.	8 usec.	4.8 usec.	1.75 usec.
	Number of words	16 to 65K	32K	16 to 65K	32 to 131K
Word length	Bits/char	—	8	—	6
	Bits/word	30	36	30	24
Number Base	—	Binary	—	Binary	Binary
Execution Speed, Fixed Point	Add (full word)	9.6 usec.	16 usec.	9.6 usec.	3.5 usec.
	Multiply (full word)	50 usec.	40 usec.	50 usec.	8.75 usec.
	Divide (full word)	70 usec.	62 usec.	70 usec.	8.75 usec.
Index Registers	Number	8	3	8	1
	Hardware or memory loc.	Hardware	Hardware	Hardware	Hardware
Indirect Addressing (yes, no)	Yes	Yes	Yes	Yes	Yes
Floating Point Hardware	None	X	—	X	—
	Standard	—	—	—	X
	Optional	—	X	—	—
Number of Instructions	62	—	62	102	—
Addresses/Instructions	1	1	1	1	1
Interrupt Control	No. of interrupt lines	16	—	28	18
	No. of interrupt registers	8	—	14	—
Special Features	55 memory reference instructions				
COMMUNICATION CONTROLS					
Max. No. of Terminals	32	—	32	64	—
Min. Data Rate (bits/sec)	50	—	50	4.5KC	—
Max. Data Rate (bits/sec)	4.8KC	—	4.8KC	1.4mc	—
Buffer Size (bits)	8	—	8	—	—
Full Duplex (yes, no)	Yes	—	Yes	Yes	—
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	800	200/800	800	200/556/800
	Tape Speed (KC)	34.2	7.2/90	34.2	75
Punched Cards	Read Speed (cards/min.)	900	800	900	400
	Punch Speed (cards/min.)	300	300	300	125
Paper Tape	Punch Speed (char/sec)	None	120	None	300
	Read Speed (char/sec)	None	300	None	120
Line Printer	No. of columns	132	120/132	132	132
	Speed (lines/min.)	700/900	800/1000	700/900	1000
Disc Storage	Capacity (char)	129 million	234 million	129 million	144 million
	Access Time (msec)	92	180	92	35
Magnetic Cards	Capacity (char)	None	—	None	None
	Access Time (msec)	N/A	—	N/A	N/A
Inter-active Displays	Numeric (yes, no)	No	—	No	Yes
	Alphanumeric (yes, no)	No	—	No	Yes
	Line Drawing (yes, no)	No	—	No	Yes
	Keyboard (yes, no)	No	—	No	Yes
	Light Pen (yes, no)	No	—	No	Yes
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines (Continued)

Models listed in ascending order by monthly lease price

	UNIVAC 494	CDC-3800	GE-625	CDC-6400	UNIVAC 1108 II
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	45	49.3	50	52	55
Lease Price Range/Month (\$ Thousands)	20 to 90	39.5 to 71	31 to 135	36 to 63	35 to 150
DATE OF 1ST INSTALLATION					
	2/66	5/64	4/65	5/66	12/65
CENTRAL PROCESSOR					
Memory	Cycle time	750 nsec.	900 nsec.	2 usec. (2 words)	1.0 usec.
	Number of words	16 to 131K	262K	32 to 262K	31K
Word length	Bits/char	—	6	6	—
	Bits/word	30	24	36 + Parity	60
Number Base	—	—	—	Binary	—
Execution Speed, Fixed Point	Add (full word)	750 nsec.	900 nsec.	3 usec.	0.6 usec.
	Multiply (full word)	7.28 usec.	5.25 usec.	7 usec.	5.6 usec.
	Divide (full word)	7.28 usec.	11.0 usec.	14.5 usec.	5.6 usec.
Index Registers	Number	8	6	12	8
	Hardware or memory loc.	Hardware	Hardware	Hardware	Hardware
Indirect Addressing (yes, no)	Yes	Yes	Yes	No	Yes
Floating Point Hardware	None	—	—	—	—
	Standard	X	—	X	X
	Optional	—	X	—	—
Number of Instructions	100	117	170	73	143
Addresses/Instructions	1	107	1	63	1
Interrupt Control	No. of interrupt lines	48	256	9	None
	No. of interrupt registers	24	10	9	26
Special Features				Core memory expandable to 2 million words	Multi-processor capabilities
COMMUNICATION CONTROLS					
Max. No. of Terminals	32	Optional	Via Datanet 30	Optional	32
Min. Data Rate (bits/sec)	50	Optional	Via Datanet 30	Optional	50
Max. Data Rate (bits/sec)	4.8KC	216mc	Via Datanet 30	12mc	4.8KC
Buffer Size (bits)	8	262K	Via Datanet 30	4K	8
Full Duplex (yes, no)	Yes	Yes	Yes	Yes	Yes
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	800	800	200/556/800	800
	Tape Speed (KC)	34.2	120	7.5 to 160	240
Punched Cards	Read Speed (cards/min.)	900	1200	900	1200
	Punch Speed (cards/min.)	300	252	100/300	None
Paper Tape	Punch Speed (char/sec)	None	350	150	None
	Read Speed (char/sec)	None	1000	500	None
Line Printer	No. of columns	132	136	136	132
	Speed (lines/min.)	700/900	1000	1200	1000
D.s.c Storage	Capacity (char)	129 million	200 million	94 million	200 million
	Access Time (msec)	92	90	199	90
Magnetic Cards	Capacity (char)	None	400 million	224 million	400 million
	Access Time (msec)	N/A	400	375	400
Inter-active Displays	Numeric (yes, no)	No	Yes	No	Yes
	Alphanumeric (yes, no)	No	Yes	No	Yes
	Line Drawing (yes, no)	No	Yes	No	Yes
	Keyboard (yes, no)	No	Yes	No	Yes
	Light Pen (yes, no)	No	Yes	No	Yes
Console Typewriter (yes, no)	Yes	Yes	Yes	Yes	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines (Continued)

Models listed in ascending order by monthly lease price

	GE-635	IBM 360/65	IBM 360/75	IBM 7094 II	GE-645
MONTHLY RENTAL					
Typical Lease/Month (\$ Thousands)	56	56.7	81.4	82.5	90
Lease Price Range/Month (\$ Thousands)	35 to 165	39 to 100	43 to 180	72 to 131	40 to 250
DATE OF 1ST INSTALLATION	6/65	3/66	4/66	4/64	7/66
CENTRAL PROCESSOR					
Memory	Cycle time	1 usec. (2 words)	750 nsec.	750 nsec.	1.4 usec.
	Number of words	32 to 262K	131 to 1024K	262 to 1048K	32K
Word length	Bits/char	6	8	8	6
	Bits/word	36 + Parity	—	—	36 + Parity
Number Base	—	Binary	Binary	Binary	—
Execution Speed, Fixed Point	Add (full word)	1.8 usec.	1.3 usec.	800 nsec.	1.4 usec.
	Multiply (full word)	7 usec.	—	—	4 usec.
	Divide (full word)	14.2 usec.	—	—	6 usec.
Index Registers	Number	12	16	16	7
	Hardware or memory loc.	Hardware	Hardware	Hardware	Hardware
Indirect Addressing (yes, no)	Yes	No	Yes	Yes	Yes
Floating Point Hardware	None	—	—	—	—
	Standard	X	X	X	X
	Optional	—	—	—	—
Number of Instructions	170	—	—	—	170
Addresses/Instructions	1	1	1	1	1
Interrupt Control	No. of interrupt lines	9 Levels	—	—	8
	No. of interrupt registers	9 Levels	—	—	9 Levels
Special Features	Memory protect				
COMMUNICATION CONTROLS					
Max. No. of Terminals	Via Datanet 30	—	—	—	
Min. Data Rate (bits/sec)	Via Datanet 30	—	—	—	
Max. Data Rate (bits/sec)	Via Datanet 30	—	—	—	To be announced
Buffer Size (bits)	Via Datanet 30	—	—	—	
Full Duplex (yes, no)	Yes	—	—	—	
PERIPHERAL DEVICES					
Magnetic Tape	Density (bits/inch)	200/556/800	800/1600	800/1600	200/800
	Tape Speed (KC)	7.5 to 160	30 to 340	30 to 340	15 to 170
Punched Cards	Read Speed (cards/min.)	900	1000	1000	250
	Punch Speed (cards/min.)	100/300	400	400	100
Paper Tape	Punch Speed (char/sec)	150	—	—	150
	Read Speed (char/sec)	500	—	—	500
Line Printer	No. of columns	136	120/132	120/132	120
	Speed (lines/min.)	1200	200/1100	200/1100	150
Disc Storage	Capacity (char)	94 million	207 million	207 million	234 million
	Access Time (msec)	199	75	75	180
Magnetic Cards	Capacity (char)	224 million	400 million	400 million	None
	Access Time (msec)	375	350	350	N/A
Inter-active Displays	Numeric (yes, no)	—	Yes	Yes	No
	Alphanumeric (yes, no)	—	Yes	Yes	No
	Line Drawing (yes, no)	—	Yes	Yes	No
	Keyboard (yes, no)	—	Yes	Yes	No
	Light Pen (yes, no)	—	Yes	Yes	No
Console Typewriter (yes, no)	Yes	Yes	Yes	No	Yes

GENERAL-PURPOSE DIGITAL COMPUTERS
Medium and Large Scientific Machines (Continued)

Models listed in ascending order by monthly lease price

		CDC-6600	IBM-360/67	IBM-360/90
MONTHLY RENTAL				
Typical Lease/Month (\$ Thousands)		117	138	5.7 million***
Lease Price Range/Month (\$ Thousands)		73 to 180	39 to 150	5.7 million***
DATE OF 1ST INSTALLATION		8/64	7/66	2/67
CENTRAL PROCESSOR				
Memory	Cycle time	1.0 usec.	750 nsec.	750 nsec.
	Number of words	31K	131 to 1024K	512 to 1024K
Word length	Bits/char	6	8	8
	Bits/word	60	—	—
Number Base		Binary	Binary	Binary
Execution Speed, Fixed Point	Add (full word)	300 nsec.	1.3 usec.	180 nsec.
	Multiply (full word)	1 usec.	—	—
	Divide (full word)	2.9 usec.	—	—
Index Registers	Number	8	16	16
	Hardware or memory loc.	Hardware	Hardware	Hardware
Indirect Addressing (yes, no)		No	No	No
Floating Point Hardware	None	—	—	—
	Standard	X	X	X
	Optional	—	—	—
Number of Instructions		73	—	—
Addresses/Instructions		1	1	1
Interrupt Control	No. of interrupt lines	None	—	—
	No. of interrupt registers	32	—	—
Special Features		Core memory expandable to 2 million words		
COMMUNICATION CONTROLS				
Max. No. of Terminals		Optional	—	—
Min. Data Rate (bits/sec)		Optional	—	—
Max. Data Rate (bits/sec)		12mc	—	—
Buffer size (bits)		4K	—	—
Full Duplex (yes, no)		Yes	—	—
PERIPHERAL DEVICES				
Magnetic Tape	Density (bits/inch)	800	800/1600	—
	Tape Speed (KC)	240	30 to 340	30 to 340
Punched Cards	Read Speed (cards/min.)	1200	1000	1000
	Punch Speed (cards/min.)	None	400	400
Paper Tape	Punch Speed (char/sec)	None	—	—
	Read Speed (char/sec)	None	—	—
Line Printer	No. of columns	136	120/132	120/132
	Speed (lines/min.)	1000	200/1100	200/1100
Disc Storage	Capacity (char)	200 million	207 million	234 million
	Access Time (msec)	90	75	180
Magnetic Cards	Capacity (char)	400 million	400 million	—
	Access Time (msec)	400	350	—
Inter-active Displays	Numeric (yes, no)	Yes	Yes	Yes
	Alphanumeric (yes, no)	Yes	Yes	Yes
	Line Drawing (yes, no)	Yes	Yes	Yes
	Keyboard (yes, no)	Yes	Yes	Yes
	Light Pen (yes, no)	Yes	Yes	Yes
Console Typewriter (yes, no)		Yes	Yes	Yes

***Purchase only — special system

GENERAL-PURPOSE DIGITAL COMPUTERS

Small-Scale Scientific/Control Computers

	BIT-480	CDC-1700	DATA-620A	PDP-8/S	PDP-9
MEMORY SIZE					
Basic Configuration (words)	1K (Characters)	4K	8K	4K	8K
Maximum size (words)	65K (Characters)	32K	32K	32K	32K
WORD SIZE					
Data Bits	8*	16	16	12	18
Memory Parity	Standard	Standard	Option	Standard	Option
Memory Protection	No	1 bit/word	Area protect**	No	No
MEMORY CYCLE (usec.)					
Store Word	8.0	1.1	1.8	8.0	1.0
Add (full word)	64 Decimal 48 Binary	2.2	3.6	46.0	2.0
Multiply (subroutine)	—	—	—	5.1 msec.	—
Divide (subroutine)	—	—	300	8.2 msec.	—
Multiply (hardware)	—	7	18	—	7 (Option)
Divide (hardware)	—	9	22	—	7 (Option)
INDEX REGISTERS					
Number in basic system	0	1 (Hardware) 1 (Memory)	2 (Hardware)	8 (Memory)	8 (Memory)
Maximum number available	0	1 (Hardware) 1 (Memory)	2 (Hardware)	8 per 4K (Memory)	8 (Memory)
MULTILEVEL INDIRECT ADDRESSING					
	Yes	Yes	Yes	Yes	No
HIGH-SPEED BUFFERED I/O CHANNELS					
Number in basic system	1	0	0	—	4 1
Maximum number available	4	2	8	—	8 1
Maximum word transfer rate (KC)	125	900	550	—	333 1000
Cycles required to set-up block transfer	4	1	4	—	5 5
Cycles stolen (from main program) per word transferred	1	1	1	—	3 1
Simultaneous I/O transfer and compute with multiple memory modules	Yes	No	Yes	—	No No
PRIORITY INTERRUPTS					
External interrupts in basic system	0	2	2	Software scanned	0
Maximum number of external interrupts	10	16	512	Cascaded indefinitely	32
Program enable/disable of individual interrupts	No	Yes	Yes	No	Yes
Program enable/disable of interrupt groups	All disabled	No	No	All disabled	Yes
CIRCUITRY					
	Integrated	Discrete	Discrete	Hybrid	Hybrid
POWER FAILURE PROTECTION					
Yes, No	No	Yes	Yes	Yes	Yes**
Automatic Re-Start	No	No	No	Yes	Yes**
COMPILER					
Basic FORTRAN	—	Yes	Yes	—	—
FORTRAN II	—	—	—	Yes (sub-set)	Yes
FORTRAN IV	—	—	—	—	Yes (real-time)
In-Line mixing with assembly language	—	No	Yes	No	Yes
ASSEMBLER (One-pass, two-pass, or both)					
	2-Pass	2-Pass	2-Pass	2-Pass	2-Pass
REAL TIME MONITOR SOFTWARE SYSTEM					
	No	Yes	Yes	No	Yes
I/O DEVICES INCLUDED IN BASIC PRICE					
	33-ASR	Console switches	33-ASR	33-ASR	33-KSR, 300 cps PTR, 50 cps punch
PRICE OF BASIC SYSTEM	\$9,600	\$37,500	\$30,900	\$9,995	\$35,000
DATE OF FIRST DELIVERY	July, 1966	April, 1966	Nov., 1965	Sept., 1966	Dec., 1966

*Variable word length

**Optional

GENERAL-PURPOSE DIGITAL COMPUTERS
 Small-Scale Scientific/Control Computers (Continued)

	EAI-640	ADVANCE 6130	GE/PAC-4020	GE/PAC-4040	GE/PAC-4050 II
MEMORY SIZE					
Basic Configuration (words)	4K	4K	4K	4K	4K
Maximum size (words)	32K	32K	32K	16K	64K
WORD SIZE					
Data Bits	16	16	24	24	24
Memory Parity	No	Standard	Standard	Standard	Standard
Memory Protection	1 bit/word	1 bit/word	Area protect**	No	Area protect**
MEMORY CYCLE (usec.)	1.65	0.9	1.6	5.0	3.4
INSTRUCTION EXECUTION SPEED (usec.)					
Store Word	3.3	1.8	3.2	15.67	6.8
Add (full word)	3.3	1.8	3.2	15.67	6.8
Multiply (subroutine)	—	—	—	2,010	—
Divide (subroutine)	—	—	—	5,344	—
Multiply (hardware)	18.15	4.8	10.5	None	16.0 to 26.2
Divide (hardware)	18.97	8.1	13.7	None	30.94
INDEX REGISTERS					
Number in basic system	1 (Hardware)	3 (Hardware)	7 (Memory)	7 (Memory)	7 (Memory)
Maximum number available	1 (Hardware)	3 (Hardware)	7 (Memory)	7 (Memory)	7 (Memory)
MULTILEVEL INDIRECT ADDRESSING	Yes	Yes	No	No	No
HIGH-SPEED BUFFERED I/O CHANNELS					
Number in basic system	4	0	0	0	0
Maximum number available	4	6	3	3	3
Maximum word transfer rate (KC)	600	1,100	625	200	294
Cycles required to set-up block transfer	1	8	5 (Accesses)	5 (Accesses)	5 (Accesses)
Cycles stolen (from main program) per word transferred	1	1	1	1	1
Simultaneous I/O transfer and compute with multiple memory modules	Yes	Yes	No	No	No
PRIORITY INTERRUPTS					
External interrupts in basic system	64	64 (Scanned)	8	8	8
Maximum number of external interrupts	64	64 (Scanned) 128 (Priority)	128	128	128
Program enable/disable of individual interrupts	Yes	Yes	Yes (16 max.)	Yes	Yes
Program enable/disable of interrupt groups	All disabled	Yes	Yes (4 per group)	Yes	Yes
CIRCUITRY	Integrated	Integrated	Integrated	Discrete	Discrete
POWER FAILURE PROTECTION					
Yes, No	Yes	Yes	Yes	Yes	Yes
Automatic Re-Start	Yes	Yes	Yes	Yes	Yes
COMPILER					
Basic FORTRAN	No	Yes	—	—	—
FORTRAN II	No	—	Extended	Extended	Extended
FORTRAN IV	Yes	—	Yes	Yes	Yes
In-Line mixing with assembly language	Yes	No	Yes	Yes	Yes
ASSEMBLER (One-pass, two-pass, or both)	1, 2, or 3-Pass	1 or 2-Pass	2-Pass	1 or 2-Pass	1 or 2-Pass
REAL TIME MONITOR SOFTWARE SYSTEM	Yes	Yes	Yes	Yes	Yes
I/O DEVICES INCLUDED IN BASIC PRICE	Console switches	33-ASR	33-ASR	33-ASR	33-ASR
PRICE OF BASIC SYSTEM	\$26,500	\$34,500	\$58,320	\$51,680	\$76,928
DATE OF FIRST DELIVERY	Feb., 1967	Mar., 1967	Oct., 1966	Aug., 1964	—

**Optional

GENERAL-PURPOSE DIGITAL COMPUTERS

Small-Scale Scientific/Control Computers (Continued)

	GE/PAC-4060	DDP-416	DDP-516	DDP-124	INTERDATA MODEL 3
MEMORY SIZE					
Basic Configuration (words)	4K	4K	4K	8K	1K
Maximum size (words)	64K	16K	32K	32K	65K (Bytes)
WORD SIZE					
Data Bits	24	16	16	24	16
Memory Parity	Standard	Option	Option	No	Optional
Memory Protection	Area Protect**	1 bit/word**	1 bit/word**	Area Protect**	No
MEMORY CYCLE (usec.)	1.7	0.96	0.96	1.75	2.0
INSTRUCTION EXECUTION SPEED (usec.)					
Store Word	3.4	1.92	1.92	3.5	35
Add (full word)	3.4	1.92	1.92	3.5	35
Multiply (subroutine)	—	311	—	—	—
Divide (subroutine)	—	—	—	—	—
Multiply (hardware)	12.6 to 22.8	—	5.28	14.0 Avg.	150
Divide (hardware)	27.54	—	10.56	19.6	200
INDEX REGISTERS					
Number in basic system	7 (Memory)	None	1 (Hardware)	1 (Hardware)	16 (Memory)
Maximum number available	7 (Memory)	None	1 (Hardware)	9 (Hardware)	16 (Memory)
MULTILEVEL INDIRECT ADDRESSING	No	Yes	Yes	Yes	No
HIGH-SPEED BUFFERED I/O CHANNELS					
Number in basic system	0	0	0	0	1
Maximum number available	3	4	20	4	1
Maximum word transfer rate (KC)	588	1,040	260	1,040	260
Cycles required to set-up block transfer	5 (Accesses)	10	6	10	3
Cycles stolen (from main program) per word transferred	1	1	4	1	1
Simultaneous I/O transfer and compute with multiple memory modules	No	No	No	No	No
PRIORITY INTERRUPTS					
External interrupts in basic system	8	1	1	None	1
Maximum number of external interrupts	128	48	48	16	256
Program enable/disable of individual interrupts	Yes	Yes	Yes	Yes	Yes
Program enable/disable of interrupt groups	Yes	Yes	Yes	Yes	All disabled
CIRCUITRY	Discrete	Integrated	Integrated	Integrated	Integrated
POWER FAILURE PROTECTION					
Yes, No	Yes	Yes	Yes	Yes**	Yes
Automatic Re-Start	Yes	No	No	No	Yes
COMPILER					
Basic FORTRAN	—	—	Yes	—	—
FORTRAN II	Extended	—	—	—	—
FORTRAN IV	Yes	—	Yes	Yes	—
In-Line mixing with assembly language	Yes	—	No	No	—
ASSEMBLER (One-pass, two-pass, or both)	2-Pass	1 or 2-Pass	1 or 2-Pass	2-Pass	1-Pass
REAL TIME MONITOR SOFTWARE SYSTEM	Yes	No	Yes	No	No
I/O DEVICES INCLUDED IN BASIC PRICE	33-ASR	33-ASR	33-ASR	IBM Selectric, 300 cps PTR, 110 cps punch	33-ASR
PRICE OF BASIC SYSTEM	\$89,016	\$15,000	\$25,000	\$65,000	\$7,900
DATE OF FIRST DELIVERY	—	May, 1967	Sept., 1966	Dec., 1965	Mar., 1967

**Optional

GENERAL-PURPOSE DIGITAL COMPUTERS
 Small-Scale Scientific/Control Computers (Continued)

	IBM-1801	IEC-1010	LC-1000	SCC-650-2	SCC-655
MEMORY SIZE					
Basic Configuration (words)	4K	4K	1K (delay line)	4K	4K
Maximum size (words)	32K	65K	65K	32K	32K
WORD SIZE					
Data Bits	16	16	16	12	24
Memory Parity	Standard	Standard	No	No	No
Memory Protection	1 bit/word	1 bit/word	No	No	No
MEMORY CYCLE (usec.)	2.0	1.0	2.5 msec.	2.0	1.75
INSTRUCTION EXECUTION SPEED (usec.)					
Store Word	4.0	2.0	156	4.0	3.5
Add (full word)	4.0	2.0	156	4.0	3.5
Multiply (subroutine)	—	—	—	—	—
Divide (subroutine)	—	—	—	—	—
Multiply (hardware)	14.5	7.0	4.5 msec.	18**	26
Divide (hardware)	42.5	7.0	4.5 msec.	18**	26
INDEX REGISTERS					
Number in basic system	3 (Hardware)	1 (Hardware)	1 (Hardware)	1 (Hardware)	1 (Memory)
Maximum number available	3 (Hardware)	2 (Hardware)	6 (Hardware)	1 (Hardware)	1 (Memory)
MULTILEVEL INDIRECT ADDRESSING	Yes	Yes	Yes	Yes	Yes
HIGH-SPEED BUFFERED I/O CHANNELS					
Number in basic system	3	0	0	0	0
Maximum number available	9	9	0	8	8
Maximum word transfer rate (KC)	500	900	—	500	570
Cycles required to set-up block transfer	6	—	—	2	2
Cycles stolen (from main program) per word transferred	1	1	—	1	1
Simultaneous I/O transfer and compute with multiple memory modules	No	No	—	Yes	Yes
PRIORITY INTERRUPTS					
External interrupts in basic system	12	8	—	1	2
Maximum number of external interrupts	384	28	—	64	64
Program enable/disable of individual interrupts	Yes	Yes	—	Yes	Yes
Program enable/disable of interrupt groups	Yes	No	—	No	No
CIRCUITRY	Discrete	Integrated	Discrete	Discrete	Discrete
POWER FAILURE PROTECTION					
Yes, No	—	Yes	No	Yes	Yes
Automatic Re-Start	—	No	No	No	No
COMPILER					
Basic FORTRAN	Yes	—	No	—	—
FORTRAN II	—	—	No	Yes	Yes
FORTRAN IV	—	Yes	No	—	—
In-Line mixing with assembly language	Yes	Yes	No	No	No
ASSEMBLER (One-pass, two-pass, or both)	2-Pass	1-Pass	1-Pass	2-Pass	2-Pass
REAL TIME MONITOR SOFTWARE SYSTEM	Yes	No	No	No	No
I/O DEVICES INCLUDED IN BASIC PRICE	Console switches	33-ASR	33-ASR	33-ASR	33-ASR
PRICE OF BASIC SYSTEM	\$47,300	\$30,500	\$12,500	\$14,800	\$27,800
DATE OF FIRST DELIVERY	Feb., 1966	April, 1967	Aug., 1966	July, 1966	Nov., 1966

**Optional

GENERAL-PURPOSE DIGITAL COMPUTERS
 Small-Scale Scientific/Control Computers (Continued)

	SCC-660	SCC-670	SIGMA 2	SEL-810A	SEL-840A
MEMORY SIZE					
Basic Configuration (words)	4K	4K	8K (Bytes)	4K	4K
Maximum size (words)	32K	32K	65K (Bytes)	32K	32K
WORD SIZE					
Data Bits	24	24	16	16	24
Memory Parity	No	No	Standard	Option	Standard
Memory Protection	Area Protect**	Area Protect**	Area Protect**	1 bit/word**	1 bit/word**
MEMORY CYCLE (usec.)	1.75	2.0	0.9	1.75	1.75
INSTRUCTION EXECUTION SPEED (usec.)					
Store Word	3.5	4	2.25	3.5	3.5
Add (full word)	3.5	4	2.25	3.5	3.5
Multiply (subroutine)	—	—	—	—	—
Divide (subroutine)	—	—	—	—	—
Multiply (hardware)	24.5	28	10-35 (Option)	7.0	10.5
Divide (hardware)	49	56	10-80 (Option)	10.5	26.25
INDEX REGISTERS					
Number in basic system	1 (Hardware)	1 (Hardware)	2 (Hardware)	1 (Hardware)	3 (Hardware)
Maximum number available	1 (Hardware)	3 (Hardware)	2 (Hardware)	1 (Hardware) 1 (Memory)	3 (Hardware)
MULTILEVEL INDIRECT ADDRESSING	Yes	Yes	No	Yes	Yes
HIGH-SPEED BUFFERED I/O CHANNELS					
Number in basic system	—	—	4 (Byte Oriented)	0	0
Maximum number available	—	—	20	8	8
Maximum word transfer rate (KC)	570	500	900	572	572
Cycles required to set-up block transfer	5	5	15	5	5
Cycles stolen (from main program) per word transferred	0 or 1	0 or 1	1	1	1
Simultaneous I/O transfer and compute with multiple memory modules	Yes	Yes	Yes	No	Yes
PRIORITY INTERRUPTS					
External interrupts in basic system	2	4	3	2	2
Maximum number of external interrupts	64	64	144	96	60
Program enable/disable of individual interrupts	—	—	Yes	Yes	Yes
Program enable/disable of interrupt groups	—	—	Yes	Yes	Yes
CIRCUITRY	Hybrid	Hybrid	Integrated	Integrated	Integrated
POWER FAILURE PROTECTION					
Yes, No	Yes	Yes	Yes**	Yes	Yes
Automatic Re-Start	No	Yes**	Yes**	Yes**	Yes**
COMPILER					
Basic FORTRAN	—	—	Yes	—	—
FORTRAN II	Yes	Yes	—	—	—
FORTRAN IV	—	—	Yes	Yes	Yes
In-Line mixing with assembly language	No	No	Yes	Yes	Yes
ASSEMBLER (One-pass, two-pass, or both)	2-Pass	2-Pass	2-Pass	1 or 2-Pass	1 or 2-Pass
REAL TIME MONITOR SOFTWARE SYSTEM	No	No	Yes	Yes	Yes
I/O DEVICES INCLUDED IN BASIC PRICE	35-ASR	IBM Selectric, 300 cps PTR, 50 cps punch	35-ASR	33-ASR	33-ASR
PRICE OF BASIC SYSTEM	\$57,000	\$64,000	\$26,000	\$23,950	\$54,500
DATE OF FIRST DELIVERY	Nov., 1965	July, 1966	Dec., 1966	Sept., 1965	Nov., 1965

**Optional

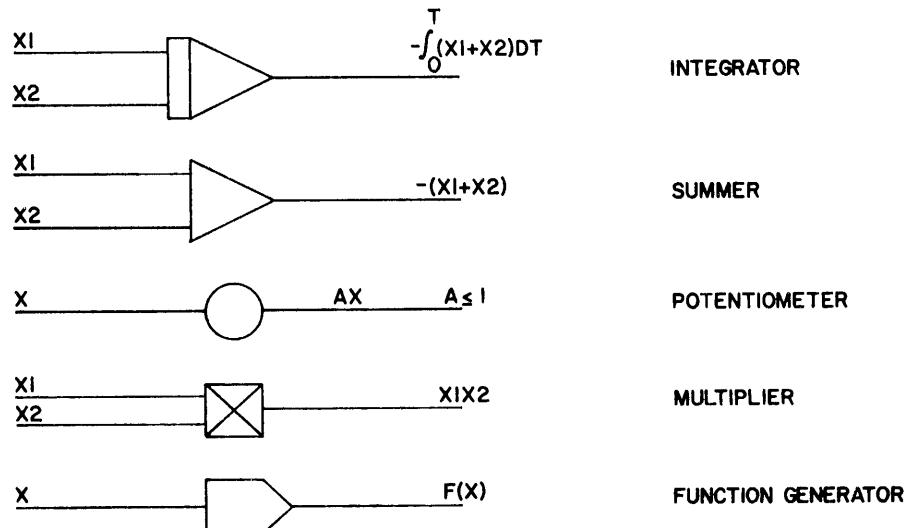
GENERAL-PURPOSE SCIENTIFIC ANALOG AND HYBRID COMPUTERS

The analog computer, formerly the main computing device for the study of dynamic systems, has been undergoing a dramatic change over the last several years. These changes have been brought about by pressure of all-digital simulation, on the one hand, and by the improved performance and reliability of solid-state components on the other hand. In addition, increased flexibility and improved computer organization, influenced in part by digital techniques, have resulted in a new generation of powerful computing systems.

The familiar analog computer of five years ago, consisting of a collection of summers, integrators,

the scientific computing market, particularly in the R & D areas where the man-machine relationship is so important. Several manufacturers have introduced new computing systems over the last year and several more may be expected. Also, several manufacturers (Reeves, Beckman, and Computer Products) have recently retired from the general purpose analog and hybrid field to devote effort to other areas, leaving Applied Dynamics, Comcor, Electronic Associates, and GPS Instrument Co., as the principal contenders covering all application areas, along with Systron-Donner in the small desktop field and Milgo in very large computers.

Fig. 1 Analog computers consist of 5 types of computing elements that may be "patched" together to simulate a mathematical model.



servo-multipliers, and potentiometers, and capable of accurate operation to about 10Hz, has been replaced by an all-electronic computer with logic control of the modes of individual components, fast switching (less than 1 usec), parallel digital logic, and capable of accurate computation to frequencies of tens of kilohertz.

Combined analog and digital computers, which until fairly recently were expensive and cumbersome special systems, have matured to the point where several manufacturers offer standard system packages with good hardware design and check-out software. Although large hybrid computers will undoubtedly be used by the large companies, an emerging trend seems to be toward smaller hybrid systems which combine a very wide-bandwidth analog computer with one of the new generation of small (12-16 bits), fast, and inexpensive digital computers.

THE MARKET

The analog and hybrid market appears to be continuing to grow at a healthy rate and, although small in comparison to the overall digital data processing market, it does represent a significant portion of

ANALOG COMPUTERS

Although there have been, and still are, many vastly different types of analog computers (mechanical, electrical, conducting surfaces, etc.), present general-purpose analog computers are exclusively electronic, based on the principle of the operational amplifier. The term "General-Purpose Scientific Analog Computer" is meant to exclude special purpose analog calculators and small operational amplifier educational units.

A general-purpose scientific analog computer consists of computing components that may be patched together to represent or simulate, electronically, a mathematical model of a physical system or process. The five basic analog components are shown in Fig. 1. The analog computer components, although unchanged functionally, have greatly improved performance over that which was available only 2 to 5 years ago. Components are all electronic, utilizing solid-state devices exclusively. Static accuracy is at least 99.99% for the summing amplifiers and integrators. Amplifier bandwidth is at least 100KHz and ranges up to over 1 Megahertz. Servoset potentiometers, digital printers and digital problem check systems permit rapid problem set-up. The hallmark of the modern analog com-

EQUIPMENT CHARACTERISTICS REVIEW

puter is the use of a second patchboard which terminates patchable digital logic, digital clocks, electronic mode and timescale control etc., permitting automatic control of the computer. High-speed, repetitive and iterative operation has become a standard mode of operation for these computers. Fig. 2 illustrates the organization of modern analog computers with digital logic control.

Repetitive operation of an analog computer involves time compression and electronic mode control. Time compression is achieved by increasing the gain of the integrators by decreasing the value of feedback capacitance. Presently-available analog computers offer timescales of 1:1, 10:1, 100:1, and 1000:1 volts/second output per volt input. A dynamic process occurring during ten seconds may be simulated in 0.001 second using a time compression ratio of 10,000:1. Electronic mode control (usually abbreviated as EMC) automatically switches the computer mode between initial condition and compute, permitting repetitive operation. Using re-

a low cost per solution. Using repetitive operation just for CRT display is wasteful of such computing capability. Statistical techniques making use of noise generators and probability distribution analyzers have made successful use of high-speed operation. Automatic parameter optimization techniques, utilizing digital logic and digital attenuators, have also been developed. Hybrid computers, with digital computer control and analysis of high-speed analog computer solutions, take full advantage of the speed of modern analog computers.

Analog Computer Specifications

Analog computer specifications are very difficult to compare. Although an attempt to standardize specifications has been made by the Simulation Council, most manufacturers disregard it. As an example, consider specifying the bandwidth of a computer. First, the bandwidth of the computer is never specified but rather the bandwidth of the amplifiers.

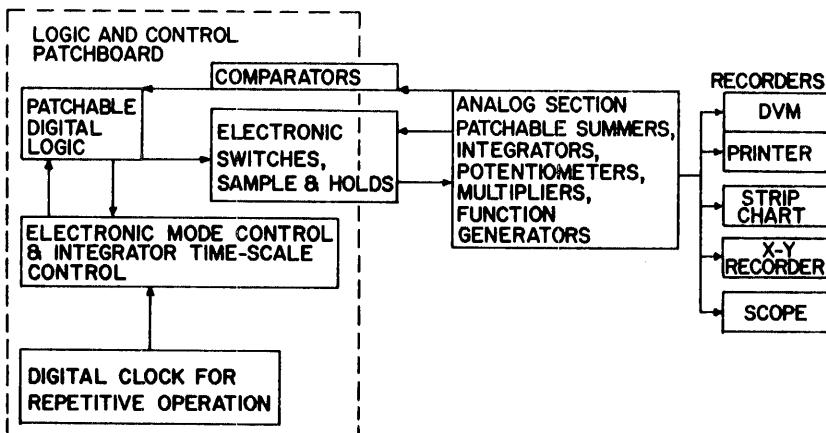


Fig. 2 Modern analog/logic control computer block diagram.

petitive operation, problem solutions may be viewed on a large screen cathode-ray tube at eye persistence rates, and the effect of parameter variations observed almost instantaneously. The EMC input is a digital clock with adjustable initial condition and compute times. The initial condition time must be sufficient for the integrator capacitors to discharge. Repetitive operation with EMC permits solution frequencies up to 50,000 per second, but requires extremely wide-bandwidth components and precise EMC switching for accurate solutions. EMC also permits multiple timescale problems and use of integrators as sampleholds, provided the integrator is capable of fast reset.

High-speed repetitive operations result in a very low cost per solution, once the problem is set up. Assume that a 150 amplifier-30 integrator facility was being rented at the rate of \$60.00 per hour; a complex non-linear differential equation of the 30th order could be solved repetitively at the rate of 1000 solutions per second. The cost per solution would be \$0.0017. This is as opposed to digital computer solution, where the equivalent cost per solution (excluding compiling, etc.) is on the order of \$2.00-\$5.00—a factor of over one hundred thousand greater. At present, the problem is utilizing the large number of solutions per second at such

Second, it is important to know at what gain and value of input and feedback resistors the amplifier bandwidth specifications was made and at what amplitude. However, it may be that the computer bandwidth is limited by the coefficient potentiometers rather than the summing amplifiers or that the amplifier bandwidth is specified with no mention made of the above conditions. The Simulation Council standards call for measuring the noise and bandwidth specifications of an amplifier as a gain 21 summer. This specification is five to ten times more severe than that for the same amplifier as an inverter with 1 gain input and feedback resistors. Similarly, the Simulation Council recommended method of measurement is "worse" by another factor of 5 over an inverter with 10 gain input and feedback resistors.

The important specifications can be classified as system specifications, number of components, component static specifications, and component dynamic specifications.

The component dynamic specifications have assumed importance in recent years as a result of the increased use of high-speed, repetitive operation. It is also in the area of the dynamic specifications that analog computers have made the most progress. Analog computers, having all component

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bandwidths in excess of 500KHz, are presently available when only a few years ago electro-mechanical multipliers and resolvers with bandwidths of at most 10Hz, were being produced. This is an increase in speed of 4 orders of magnitude while, at the same time, analog-computing element reliability has increased by an order of magnitude through the use of solid-state computing components. The emphasis for wide-bandwidth analog computers has been largely responsible for the increasing use of 10 volt systems.

Though the low-frequency signal-to-noise ratio is slightly lower than for 100 volt systems, the dynamic performance of 10 volt systems is invariably better. The trade-off point between 10 and 100 volt systems in terms of accuracy is as low as 1000Hz. The emphasis on bandwidth has also greatly influenced most computer component layouts. The trend in analog computers is to have the computing components located directly behind the patchbay, accessible from the front of the computer when the patchboard is removed. Therefore, the serious bandwidth deterioration that results from long cable lengths is removed. Solid-state components have reduced the size of analog computing elements by a factor of about 5:1 while, at the same time, greatly reducing the requirement for air conditioning.

The stringent requirements for bandwidth and EMC specifications are a result of repetitive operation. At solution rates of 100 to 1000 per second, solution frequencies are of the order of 10KHz. In order to have less than 1° of phase shift at 10KHz, the amplifier bandwidth must be 1 megacycle. Since the amplifier bandwidth is a function of the gain, this implies a very large gain-bandwidth requirement for accurate dynamic solutions. Another important component dynamic requirement is the EMC switching. An equivalent phase shift error is introduced if all integrators are not set and reset at precisely the same time. In order to have the equivalent of less than 1° of phase shift at 10 KHz introduced by the integrator EMC, all integrator EMC electronic switches must open and close within 200 nanoseconds; this is referred to as the aperture time.

Analog Computer Applications

Analog computers are finding application in many diverse fields such as:

- Aircraft and missile control systems and dynamic analysis;
- Process control simulation;
- Chemical and electrochemical modeling;
- Structural dynamics analysis;
- Electronic network transient analysis;
- Life sciences mathematical modeling and simulation.

A general rule governing analog computer application is that the problem must at least involve differential equations. Beyond this, current practice in analog computation involves many new techniques such as automatic iteration for boundary value and partial differential equation problems, multiple timescale, repetitive operation, automatic parameter search and optimization, statistical tech-

niques, etc. Newer methods are constantly being developed to take advantage of the capabilities of the modern analog and hybrid computer and to provide the more sophisticated computing techniques required by today's mathematical techniques.

Analog computers perform both simulation and computation. The distinction between these two words is that simulation involves the modeling of a physical system; computation is the process of solving equations. Analog computers have traditionally been "simulators", while digital computers have traditionally been "computers." This is no longer true. With the development of simulation languages, digital computers are now starting to be used for simulation, and analog computers are increasingly used for computation. Small and inexpensive analog modules for instruments and control systems are increasingly popular. What is the future for analog computers? The following observations should indicate some trends.

- Analog computer real-time, slow speed simulation, especially when operated with actual system hardware, will gradually be replaced with digital computer simulation if digital computer processing speeds continue to increase and if more accurate numerical integration techniques are developed. Analog computers employing electromechanical computing components have been obsolete for at least five years.
- Modern wide-bandwidth, repetitive operation digitally-controlled analog computers will have many areas of application, especially with the continued development of advanced computing techniques. The biggest present problem appears to be the education of potential users of the capability of these machines. Many scientific problems can be solved quicker and cheaper with this type of machine than with a digital computer. At the same time, because analog computers directly simulate physical systems, more insight to the problem can be obtained.
- Hybrid analog/digital computers combining the advantages of both analog and digital computers will probably move toward much more widespread usage due to the increasingly complex problems that need to be solved. Again, a large problem exists in educating potential users and management of the usefulness of this type of machine as well as the further development of software to permit more efficient utilization.

Some general advantages of analog computers are:

- Well-suited to solving differential equations;
- Parallel operation;
- Ease of problem set-up;
- Parameter variations easily performed;
- Easy graphical presentation of results;
- Excellent man-machine relationship.

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Some general disadvantages of analog computers are:

- Limited precision;
- Limited memory;
- Difficult to generate functions of more than one variable.

HYBRID COMPUTING SYSTEMS

Hybrid computing systems consisting of analog and digital subsystems, connected with the proper data conversion and controls, have evolved into very powerful computing systems which combine the advantages of both the analog and digital parts with only minor disadvantages arising from the errors introduced by the process of sampling and converting data from analog-to-digital and vice-versa.

but the cost would be considerably higher.

The inputs to the analog multiplexer are generally buffered with simultaneous sample-holds to avoid time-skew errors during the multiplexing and conversion process and, for the same reason, the digital-to-analog converters generally are "double-buffered" with two sets of registers. It should be recognized that it is at these two points where the parallel computations of the analog and the sequence computations of the digital are separated, i.e., the parallel analog signals must be sequentially entered into the digital computer memory and the digital data must be read out sequentially and constructed so as to appear as parallel data for the analog computer. This process may be accomplished with minimum delay when the A-to-D and D-to-A channels use direct access to the memory of the digital processor.

A group of sense lines are provided to enable

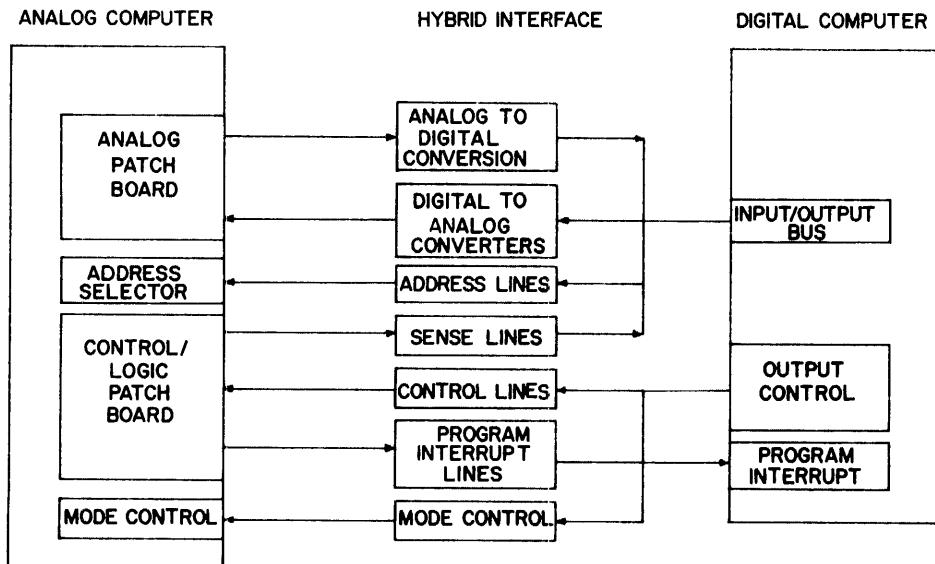


Fig. 3 Typical hybrid computer functional block diagram.

The digital portion of these systems provides the storage (memory), precision, and function generation capability that is difficult to obtain in a pure analog computer and provides the capability for rapid set-up of coefficients, program testing, and bookkeeping operations. Automation of sequences of computer runs and adjustment of parameters between runs provides increased efficiency of operation. At the same time, all of the advantages of the analog computer are retained—rapid solution rates because of parallel operation, true integration, rapid and on-line changes of both the problem and parameters, and excellent man-machine communication.

As shown in Fig. 3, most hybrid computers use a modern wide-bandwidth, general-purpose analog computer with digital logic, a fast general-purpose digital computer, and a group of components to transfer data between the two general-purpose computers. The analog-to-digital data transfer is generally accomplished through a multiplexer and a single analog-to-digital converter while the digital-to-analog data transfer uses multiple digital-to-analog converters. That most present systems use a multiplexer and single A-to-D converter is an economy-performance tradeoff. Faster operation would be obtained with separate A-to-D converters

the digital computer to inspect the status of events on the analog computer's logic patchboard. Control lines that are set and cleared by digital computer instructions provide the means for controlling the state of analog elements—again generally via the logic patchboard. Priority interrupt lines enable events on the logic patchboard to interrupt the digital computer for modification of the program via skip or branch instructions.

Most systems also provide the digital computer with access to the analog computer's mode control address selector and coefficient pot setting system. With this assortment of interface components, these systems have the capability of performing both hybrid computations and a high degree of automation of problem, set-up, checkout, run sequencing, and data collection.

Hybrid Computer Specifications

In addition to the analog computer specifications previously discussed, the primary hybrid system and component specifications are the digital central processor, analog-digital data transfer, and the discrete controls. There are, of course, many more factors, both hardware and software, which affect the total system performance. Reference to

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the section on digital computers is recommended for complete description of the digital machine features and characteristics.

In the A-to-D and D-to-A subsystems, all manufacturers appear to be using state-of-the-art converter systems with sufficient accuracy for most problems. Some caution in comparing conversion rates is needed, however, since some manufacturers specify actual conversion rates with multiplexer address and central processor I/O instruction times included, while others specify only the time of the converter itself or in some cases, time-per-bit rather than per word. Direct memory access for the converter systems is available in most of the computers and is a worthwhile (but costly) feature from the standpoints of both time required for the conversion itself and the number of instructions required in the programming.

The method of handling the discrete controls is perhaps the greatest difference between machines. The number of instructions required to achieve the discrete data format varies widely with the exact hardware arrangements. For example, one

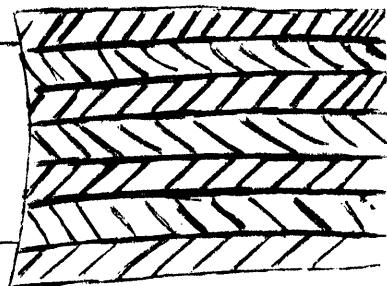
computer may require that an output data bus be loaded with all control line bits and a second instruction is used to load the control line flip-flops, while a second uses individual I/O instructions for each control line permitting a single instruction and program step to set or clear a line. Similar differences appear in the time required for the sense lines and interrupts.

All models surveyed in the product summary charts following this text provide, as standard equipment, at least a typewriter and slow speed paper tape reader/punch for program and data input/output, and all manufacturers offer a fairly complete line of standard digital computer peripherals as optional equipment. All manufacturers also provide a standard software package and offer additional applications programs.

In addition to the manufacturers who offer standard hybrid systems (mainly analog computer manufacturers), most digital computer manufacturers and analog-digital converter manufacturers offer special interface packages for use with existing analog computers.

memo:

*See Product Category 3
in the Product Directory
for complete names and addresses
of Analog and Hybrid
Computer Manufacturers*



GENERAL-PURPOSE ANALOG COMPUTERS

MANUFACTURER	APPLIED DYNAMICS		COMCOR		ELECTRONIC ASSOC.			GPS INSTRUMENT				HITACHI	MILGO	SIMULATORS		SYSTRONDONNER	
MODEL	AD-80	AD 4	CI-175	CI-5000	TR-48	680	8800	200T	390T	10000T	10000T2	505	4100	240	480	10/20	40/80
SYSTEM SPECIFICATIONS																	
Operational range (volts)	100	100	100	100	10	10	100	10	10	100	100	100	100	10	10	100	100
Shielded problem board	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Separate logic patchboard	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Price range (\$000)	—	50-400	—	—	—	—	To 500	25-70	40-150	40-200	50-400	—	—	2-18	5-50	6-12	16-60
NO. OF COMPONENTS																	
Amplifiers (total)	68	288	75	416	48	156	338	64	154	192	360	62	500	28	56	28	84
Integrators	24	64	24	60	16	30	66	16	16	32	52	18	40	12	24	12	30
Summers	40	48	24	60	32	24	60	32	16	64	96	62	80	12	24	20	60
Manual coeff. pots	0	12	10	32	60	12	—	60	20	32	32	54	0	30	60	24	125
Servoset pots (or digital attenuators)	80	244	70	192	0	120	240	0	64	96	160	—	200	4	4	0	0
Multipliers	10	64	12	72	5	24	72	12	24	28	44	5	72	6	12	4	20
Diode function generators	14	24	13	32	12	42	30	4	16	24	34	3	28	8	16	4	15
Integral digital logic elements	45	182	58	121	NA	68	227	90	90	180	180	34	220	78	78	18	30
STATIC SPECIFICATIONS																	
Component matching inaccuracy (percent)	0.01	0.005	0.01	0.0025	0.01	0.005	0.005	0.01	0.005	0.005	0.005	0.01	0.005	0.01	0.01	0.01	0.01
Amplifier dc gain	10^8	2×10^8	5×10^7	10^8	10^7	3×10^7	2×10^7	10^7	10^7	1.5×10^7	1.5×10^7	6×10^7	2×10^8	4×10^7	4×10^7	10^7	10^7
Noise-summer SCI loads, gain 21 (mv)	—	—	20	25	—	4	25	2	2	15	15	—	—	—	—	2	2
Max. amplifier output current (ma)	—	35	50	50	20	30	35	50	50	35	35	25	30	33	33	25	25
Integrator real-time drift (microvolt/sec.)	—	50	60	60	50	10	—	10	10	100	100	50	—	5	5	100	100
Multiplier static accuracy (percent)	0.04	0.015	0.025	0.025	0.06	0.025	0.01	0.1	0.025	0.015	0.015	0.02	0.02	0.01	0.01	0.07	0.07
DYNAMIC SPECIFICATIONS																	
Bandwidth-summer, unity gain	100	200	40	125	50	500	100	1000	1000	1000	1000	100-300	70	—	—	50	50
Bandwidth-summer SCI loads (gain 21)	—	—	10	15	35	125	20	1000	1000	1000	1000	—	16.5	175	175	20	20
Phase shift at 1KHz-summer SCI loads	—	0.01	0.5	0.5	0.2	0.32	0.30	0.05	0.05	0.05	0.05	0.3-0.1	0.3	0.2	0.2	1.2	1.2
Amplifier velocity limit (volts/usec.)	7	25	10	20	—	25	20	25	30	20	20	20	15	2	2	3	3
Max. frequency at full output (KHz)	—	40	—	—	—	500	40	1000	1000	50	50	30	10	—	—	1.5	1.5
Noise-summer, unity gain (mv)	6	4	10	6	—	2	10	2	1	—	—	4	5	0.8	0.8	10	10
EMC aperture time (usec.)	—	1	2	2	NA	1	1	1	1	1	1	1	—	2	2	—	—

GENERAL-PURPOSE HYBRID COMPUTERS

MANUFACTURER	ADAGE	APPLIED DYNAMICS	ELECTRONIC ASSOCIATES, INC.	
MODEL NUMBERS				
Hybrid System Model	Ambilog 200	AD4/4090	EAI-690	EAI-8900
Analog Computer Model	NA	AD4	EAI-680	EAI-8800
Digital Computer Model	NA	AD4090	EAI-640	EAI-8400
Interface System Model	NA	—	EAI-693	EAI-8933
DIGITAL CENTRAL PROCESSOR				
Word Length (bits)	30	18	16	32
Core Memory Capacity	4 to 32 K	32K	8 to 32 K	16 to 65 K
Memory Cycle Time (usec)	2.0	1.0	1.65	1.0
Fixed Point Add (usec)	4.0	2.0	3.3	2.5
Floating Point Add (usec)	—	—	382	3.4
Fixed Point Multiply (usec)	10.0	11.0	18.15	4.8
Floating Point Multiply (usec)	—	—	609	6.2
Time Sharing/Multiprocessor Modes	Yes	No	No	Yes
Background/Foreground Processing	—	—	Yes	Yes
A to D DATA TRANSFER				
A to D Channels (std/max)	8/128	32	24/24	16/128
A to D Word Length (bits)	15	15	14	14
A to D Conversion Rate (words/sec)	125 KC	—	30 KC	85 KC
Direct Memory Access	No	Yes	Yes	Optional
D to A Channels (std/max)	8/128	256	24/24	16/128
D to A Word Length (bits)	15	14 to 16	14	14
D to A Conversion Rate (words/sec)	500 KC	—	300 KC	100 KC
Double Buffered	Yes	Optional	Yes	Yes
Direct Memory Access	No	Yes	Yes	Optional
DISCRETE CONTROLS				
Analog Mode and Address Control	Yes	Yes	Yes	Yes
Sense Lines (std/max)	30/unlimited	16/256	8/8	8/32
Control Lines (std/max)	30/unlimited	16/256	16/16	8/32
Priority Interrupt Lines (std/max)	5/25	8/32	8	8
PRICE RANGE (\$000)	150-1000	100-600	150-400	750-1,250
COMMENTS		Choice of 24 or 32 bit digital computer, D to A channels include potentiometers	Word includes 16 data bits plus protect bit	Word includes 32 data bits, 1 protect bit, 1 parity bit

GENERAL-PURPOSE HYBRID COMPUTERS (Cont'd.)

MANUFACTURER	G P S INSTRUMENT COMPANY			
MODEL NUMBERS				
Hybrid System Model	GPS 290T	GPS 390T	GPS 10000T/918	GPS 10000T/932
Analog Computer Model	GPS 200T	GPS 390T	GPS 10000T	GPS 10000T
Digital Computer Model	GPS DPC912	GPS DPC918	GPS DPC918	GPS DPC932
Interface System Model	GPS HI-290	GPS HI-390	GPS HI-10K	GPS HI-10K
DIGITAL CENTRAL PROCESSOR				
Word Length (bits)	12	18	18	32
Core Memory Capacity	4 to 32 K	8 to 32 K	8 to 32 K	8 to 132 K
Memory Cycle Time (usec)	1.5	1.0	1.0	0.9
Fixed Point Add (usec)	3.0	2.0	2.0	2.06
Floating Point Add (usec)	405	80	80	6
Fixed Point Multiply (usec)	15	11.0	11.0	10.0
Floating Point Multiply (usec)	530	350	350	10.0
Time Sharing/Multiprocessor Modes	No	No	No	Yes
Background/Foreground Processing	No	Yes	Yes	Yes
A to D DATA TRANSFER				
A to D Channels (std/max)	8/64	16/64	16/64	16/128
A to D Word Length (bits)	12 (14 bits optional)	14 or 15	14 or 15	14 or 15
A to D Conversion Rate (words/sec)	30KC (200 KC optional)	30 KC (200 KC optional)	30 KC (200KC optional)	100 KC
Direct Memory Access	Optional	Optional	Optional	Yes
D to A Channels (std/max)	4/16	8/32	8/64	16/128
D to A Word Length (bits)	12 (14, 15 optional)	14 or 15	14 or 15	14 or 15
D to A Conversion Rate (words/sec)	100 KC	500 KC	500 KC	500 KC
Double Buffered	Yes	Yes	Yes	Yes
Direct Memory Access	Optional	Optional	Yes	Yes
DISCRETE CONTROLS				
Analog Mode and Address Control	Yes	Yes	Yes	Yes
Sense Lines (std/max)	12	16	16	16
Control Lines (std/max)	8/12	16	16	16
Priority Interrupt Lines (std/max)	1/12	1/32	1/32	8/244
PRICE RANGE (\$000)	60-200	95-350	100-500	250-750
COMMENTS	Can also be adapted for PDP-9, DDP-516 or Sigma 2 digital computers	Can also be adapted for PDP-8, DDP-516, or SIGMA 2 digital computers	Can also be adapted for PDP-8, DDP-516, DDP-124, or Sigma 2 digital computers	Word includes 32 data bits 1 protect bit and 1 parity bit. Can also be adapted for PDP-10 digital computer

DATA COMMUNICATIONS TERMINALS AND SPECIAL PROCESSORS

The term "Data Communications" is today generally used to identify the technology by which recorded information is exchanged between geographically-separated parties, with the understanding that this information either originates in, or is destined for, a computer. Although there is a tendency in the computer industry to regard data communications as a new technology, a by-product of military command-and-control, etc., the historical fact is that much of this technology is directly founded upon principles and practices that were established in the record-communications or telegraph field long before digital computers were a practical reality. What is new and important is the large-scale use of this technology in modern commerce. This large-scale use has been brought on both by the great demands of modern institutions for integrated information management within geographically dispersed organizations and by the capability of modern computer technology to serve these needs economically.

While it has been correct in the past to characterize data communications in this computer-oriented sense as a new and emerging technology, the combination of demand, technology, and successful experience over recent years has caused this characterization to change. It is now more nearly correct to characterize data communications as a significant aspect of many information processing problems which must naturally be considered by the system designer. Functionally, one can say that whenever the elements of geographic dispersion, "impatience" for answers, and ultimate involvement of a computer system are present, there is a case for consideration of this technology.

The current and anticipated economic balances further stimulate demand for the computer-based solution to these problems. Civilization grows more complex and its demands for information increase yearly, while computer processing capability per dollar of cost continues to jump significantly every three years or less. Moreover, satellite and laser technologies offer the prospect on a somewhat longer time scale of significant decreases in the costs of communications facilities.

In this survey of data communications technology, particular emphasis is given to the problems of equipment selection. In any application of this type, there are three major equipment considerations: computational facilities, terminal facilities, and communications facilities. Selection of computational facilities necessarily involves an examination of the entire information processing problem and is considered beyond the scope of this article, except for a discussion of relatively specialized communications processors.

Basic Characteristics of Data Communications Systems

A data communication system, functionally speaking, is any system which permits recorded information to be exchanged between a number of geographically-dispersed parties, the information either originating in, destined for, or somehow associated with a digital computer system. This rather broad definition, while correctly defining systems within the scope of this section, needs a more detailed development to take on full meaning. A critical consideration not explicitly stated in this definition is the time element. While it is technically correct to state that a system employing the U.S. Mail as a communications facility and off-line keypunching of computer input provides all the requisites, it is clear that this is only trivially true. Within the context of this section, a data communication system must achieve communication between distant users at essentially conversational speed, as though there were no intervening distance nor a necessity to wait more than a few minutes to hold the conversation.

The purely functional description, even with the time factor considered, does not adequately describe the data communications system nor distinguish it from other functionally-similar systems. An adequate development of a description must necessarily consider techniques commonly employed, applications commonly served, and design problems that commonly arise.

A discussion of techniques for data communication system implementation covers such subjects as: system structure, terminal devices, system control devices, communications facilities, and modes of communication. These subjects are discussed below.

Structure

The simplest possible system structure is that of the point-to-point connection. Two users talk to each other, but to no one else. The physical implementation is that of a single line connecting two terminals.

Next in complexity is the party-line structure. Several users share the same line. Many pairings of conversations are possible but little organization is achievable on a system basis.

The most simple yet orderly structure for a system with many users is the Star structure in which all users communicate with a central point which has supervisory control over the system. Users communicate with each other only by permission

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of this central supervisor.

The most elegant system structure is the multiple Star configuration in which there are several central supervisory points, each with its own set of end users, and a means for direct communication between the central points.

Terminal Devices

Each "conversation" in a data communication system requires a pair of terminals. A terminal must provide the user with three capabilities:

1. Interfacing the user (through a keyboard, etc.) and storing large quantities of information when necessary;
2. Buffering the transmission to compensate for fundamental differences in speed between the user interface device and the communications channel's operational capability;
3. Controlling the transmission by monitoring the data stream and exchanging supervisory information with the other party.

These capabilities may be supplied in a free-standing independent terminal device or as a time-shared function in the communications interface of a computer system.

A wide variety of terminal devices are on the market today. All types of user interface, buffering, and control approaches are available. Products are characterized in accordance with:

1. Types of interface (card, paper tape, magnetic tape, keyboard, CRT display);
2. Speed (generally three ranges corresponding to common communications channels—5 to 15 char/sec., 150 to 300 char/sec., and 15,000 char/sec., to microwave speeds);
3. Mode of communications (e.g., block-by-block, inquiry-response).

Data communications terminals generally exhibit certain common characteristics which also serve to distinguish them from terminating devices in other real-time applications. These characteristics are:

1. Use of the alphanumeric data format—characters, blocks of characters, and multi-block messages;
2. Extensive controls in data and procedures to detect and correct errors;
3. General design features oriented toward the operational requirements of common carrier facilities;
4. Speeds of transmission that reflect economic combinations of interface devices and common carrier facilities.

SYSTEM CONTROL DEVICES

System control is today almost universally implemented through use of stored-program computer systems. Prior to the availability of these machines such control was implemented by wired logic. For the past ten years, computers have been utilized for control of all new applications except for certain relatively simple cases where special-purpose wired logic enjoyed a momentary economic edge. With the advent of the "less-than-\$10,000" computer with a

core memory, such as Digital Equipment Corporation's Model PDP-8/S plus other comparable new product announcements, there is little reason to give further consideration to wired logic for control functions of any consequence. (Logic solutions will, of course, continue to be important in the communications line interface portion of computer systems.)

Functionally speaking, system control is closely associated with the requirements of the end use of the system. Certain functions are fundamental, such as channel control, traffic management, message interpretation, language translation, and recoveries from equipment malfunctions.

COMMUNICATIONS FACILITIES

The concept of distance which characterizes most data communications applications is that of "many miles." Consequently, it is usually necessary to think in terms of obtaining communications facilities from the common carriers. Here again is a basic characterization of data communications systems which distinguishes them from other real-time computer systems used, for example, in process control, scientific laboratories, and the military/aerospace environment.

The organization and division of capability in the common carrier plants was generally determined long before the emergence of computer technology. These concepts of organization were (and still are) influenced primarily by the requirements of teleprinters, voice, broadcast radio, and broadcast television transmissions. A departure from these concepts, even if strongly motivated, will be slow because of the enormity of the systems involved. It is for this reason that one speaks of communications facilities as being "available" as opposed to being "designed".

The user normally views communications facilities as a set of channels of a given bandwidth. These channels may be viewed as either direct lines between the terminals of his system or as lines from his terminals into a common-switched system whose switching capabilities are usable. These channels are generally classified into three groups.

1. Teleprinter channels basically capable of handling the load generated by a manually-operated keyboard device such as a teleprinter. A nominal speed range for these channels is 10 char/sec to 15 char/sec.
2. Voice-grade channels basically designed for handling voice transmissions and normally able to handle data at speeds up to 150 char/sec. Specially prepared voice channels can handle data up to 600 char/sec.
3. Broadband channels basically capable of handling data transmissions at a variety of levels up to any practical requirement into the scale of megabits/sec.

Channels may be unidirectional, alternatively reversing unidirectional, or simultaneously bidirectional. While a channel may appear to the user as a single data path, it takes on a variety of guises within the communications plant. The probability of error-inducing noise increases when:

1. Great distances are involved;

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2. A given data channel passes through many switching points;
3. The common carrier alters the physical equipment used to implement the channel.

(presumably very few) where correction is not possible, re-transmission is arranged as in the "check and stop transmission" mode.

This noise causes transmission errors on the order of 1 in every 10,000 to 100,000 characters. These error rates are sufficiently high to justify use of simple detection and correction schemes, particularly when direct computation is required upon the information when delivered.

COMMUNICATIONS MODES

The manner in which information is exchanged, or the mode of communication, is generally a function of the application. The following modes are commonly experienced.

1. Block-by-block transmission: This mode is used for the transmission of large quantities of data. Blocks are generally fixed in size, 80 characters being popular for obvious reasons. A long transmission may involve thousands of blocks.
2. Inquiry-response: This mode is used for obtaining answers from, or placing orders on, a central control and repository system. Messages are short and formats highly tailored to the application to obtain efficiency in transmission and to minimize the incidence of incorrect requests or non-executable orders.
3. Data entry or distribution: For certain applications a unidirectional version of either of the first two modes is possible.
4. Store-and-forward message control: This mode of communications distinctively involves exchanges of data between two users through the intermediary of a central system which accepts responsibility for completion of the transmission and maintains long-term supervisory control of a group of users. The times of receipt and delivery of a message are generally not the same.

For all of these basic modes there exists a subgrouping of data channel operational modes that depend more on the method of error control employed on the channels than on the user-oriented nature of the transmission. These modes are listed below.

1. Uncontrolled transmission: No checks are performed and no mechanical corrective measures exist.
2. Check and stop transmission: Checks are performed on the data as received on a block basis and the transmitter requires acknowledgement of each block before sending the next. Corrections occur by operator intervention.
3. Check and re-transmission: Checks and acknowledgement are performed as above, but rejected blocks are re-transmitted automatically and the operator is called only when repeated re-transmissions fail to get a block accepted.
4. Forward-corrective transmission: The data is encoded using a highly-redundant, self-corrective scheme. The receiving station decodes the data and corrects the detected errors which are capable of correction. For those cases

Applications

Real-time computer systems have many applications. The distinctions which exist among these applications form the basis for the following user groupings:

1. Commercial
2. Industrial
3. Scientific
4. Military/Aerospace

The commercial area of application is essentially synonymous with data communications as we have defined it and is the particular subject area of interest in this section. Brief mention of the characteristics of the other areas will first be made for clarification.

The industrial area of application involves process control, on-line production control, and automatic inspection systems. Industrial data-gathering applications are considered to fall in the commercial area because their implementation has characteristics in common with many commercial systems.

The scientific area of application involves principally the instrumentation of laboratories for physical and biomedical experimentation.

The military/aerospace area involves tactical and strategic command and control, range instrumentation, count-down, onboard guidance, and other exotic applications.

Within the commercial area there exist many different types of applications. Commercial message switching systems have existed for years, particularly so if one considers the fairly substantial pre-computer relay-actuated systems built by A. T. & T. and Western Union for public and private networks. The oldest commercial systems in the computer era are found in airline reservation and stock brokerage applications where urgency to save time created economic justification long ahead of other areas. The list of commercial applications is steadily growing today. Some indication of the variety is given below.

- Message switching
- Airline reservation
- Hotel reservation
- Brokerage transactions
- Brokerage ticker service
- Branch banking
- Credit checking
- Multiple-warehouse order processing
- Truck or rail system management
- Computer aided instruction
- Computer aided design
- Hospital administration
- Customer account inquiry processing
- Retail point-of-sales inventory control
- Time-sharing computational facilities
- Load-sharing between computers

Design Considerations

The design of a complete data communications system can be an exceedingly complex task. If large numbers of terminal points and many processing

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functions are involved, the design study will be complex not only because of the size of the system presumably required, but because it will be necessary to become concerned with the ultimate use of the system. Ultimately this analysis must be translated into a statement of the traffic load for which the system is to be engineered. Some idea of the possible breadth of this statement can be gathered from Table 1.

TABLE 1
Traffic Load Considerations

1. IDENTIFICATION AND DESCRIPTION OF ALL MAJOR FUNCTIONS TO BE PERFORMED BY THE COMPUTER SYSTEM.
2. LOAD CHARACTERISTICS FOR EACH MAJOR FUNCTION.
 - A. Average rate: requests/unit time
 - B. Peak rate: requests/unit time
 - C. Data input per request (average and/or peak)
 - D. Data output per request (average and/or peak)
 - E. Internal data transfer rate per request
 - F. Response time per request average
 - G. Response time per request worst-case
 - H. Relative priorities of different types of functions
3. TRAFFIC LOAD IMPOSED ON EACH COMMUNICATION CHANNEL DUE TO DATA INPUT/OUTPUT FOR REQUESTS FOR FUNCTIONS.
 - A. Average rate: requests/unit time
 - B. Peak rate: requests/unit time
 - C. Average data input per request (should be identical with 2C)
 - D. Average data output per request (should be identical with 2D)
 - E. Peak data input per request
 - F. Peak data output per request
 - G. Average percentage load on communication channel
 - H. Peak percentage load on communication channel
4. STORAGE REQUIREMENTS FOR ALL FUNCTIONS
 - A. Access in microseconds
 - B. Access in 1 to 1000 milliseconds
 - C. Access in seconds
 - D. Accounting and record keeping
 - E. Duplication for protection
5. RELIABILITY REQUIREMENTS
 - A. Acceptable down-time for system: average duration, frequency of outages
 - B. Availability of time for scheduled maintenance
 - C. Acceptable delays in recovery after system failure; security responsibility of system where failure occurs
6. LANGUAGE AND CONTROL
 - A. Formats: variety and "looseness"
 - B. Checking procedures
 - C. Supervisory handling of special problems

For the specific problem of selecting a terminal device, the design analysis reduces to a simpler form. Traffic volumes and acceptable delays are more easily assessed on an individual channel basis. Because of the break-points in terminal capabilities imposed by equipment availability (teleprinter, voice and broad-band channels basically), the designer does not have an infinite spectrum of capabilities to choose from and tests of adequacy rather than precise matching of capabilities must often be made.

The most significant design consideration affecting terminal selection is that of matching the terminal's functional capability to the functional requirements of the application. The best evidence of this importance lies in the variety of special-purpose terminals developed for such applications as airline reservation systems, on-line banking, industrial data collection, and brokerage board rooms.

Data Terminals, Block by Block

The block-by-block data terminal is the basic data transmission workhorse. Its primary use is for transmission of variable, but usually large, quantities of data between two points. Its functional prototype, the teleprinter, generally suggests the product's characteristics and adaptability: messages of any length can be transmitted, and alphanumeric codes are used. Use of the term "block-by-block" to identify this class of products has the purpose of connoting both large quantities of data and the transmission of this data in blocks rather than in a continuous data stream of indefinite length.

The basic functional characteristics of this group of data terminals are given below. Many of these characteristics are, incidentally, shared by the next group of terminals discussed, "inquiry-response". The basic functions of this group of terminals are:

1. To provide an interface between the end user's data media (card, paper tape, etc.) and the transmission facility;
2. To provide a bulk storage capability for message accumulation or transmission;
3. To achieve compatibility between the interface and storage devices and the transmission facility through speed and code conversion;
4. To control the transmission, detect, and correct errors.

Performance of a data terminal in this group is primarily a function of the type of I/O interface capability it provides and its achievable transmission speed. Other features of its design are all generally secondary in that their effect is manifested in these two fundamentals.

The physical implementation of a block-by-block data terminal consists of three sections:

1. The I/O interface device;
2. The control unit;
3. The transmission facility interfacing unit.

Many types of I/O interfacing devices exist. They all combine the functions of the interface and bulk storage into one unit. Devices commonly found include:

1. Teleprinters;
2. Paper tape readers and punches;
3. Card readers and punches;
4. Magnetic tape units;
5. Page and line printers.

The control unit houses the communications functional capability of the terminal. Functions commonly performed include:

1. Data transmission control—operation of the terminal to move data between the I/O device and the transmission facility;
2. Code conversion between I/O device code and transmission code;
3. Generation of error-detection codes during transmission and detection of errors during receipt, plus signalling data transmission control to acknowledge or reject data which has been checked;
4. Serial-to-parallel conversions and synchronization;
5. Coordination with operator;

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6. Provision of temporary storage, where necessary, to accommodate speed differences between I/O device and transmission facility capability.

The transmission facility interfacing unit changes the form of information from the characteristic digital form of the terminal to the usual characteristic audio frequency form of the transmission facility. This device, usually referred to as a "modem", may be considered a part of the terminal or a part of the transmission facility depending on who furnishes it (the terminal vendor or the common carrier).

TABULAR PRODUCT PRESENTATION

The charts at the end of this section present listings of data terminals currently on the market that are intended for lengthy message transmissions, hence are classed "block-by-block". Within this group, the terminals are generally sub-classed by I/O device because this is the most fundamental distinguishing property. The type of I/O device employed always fixes the transmission speed capability of the terminal and almost always determines the level of error detection and correction used. The other remaining properties of these terminals are generally fixed once the I/O device is chosen.

The speed of a data terminal is limited by either the I/O device's capability or the transmission line's capability, whichever is less. Examination of the terminals on the market today and the general use that is made of communications facilities shows that in some cases the I/O device and communications facilities limits are comparable whereas in others, one limit is grossly below the other. A brief comparison is made in Table 2 to show how these limits

TABLE 2

BALANCING OF I/O DEVICE AND COMMUNICATIONS CHANNEL TRANSMISSION SPEEDS		
I/O Device Group and Nominal Speed	Communications Facility and Nominal Speed	Comment
Teleprinter or low-speed card at 10 char/sec.	Teleprinter Channel at 10 char/sec.	Balanced
Teleprinter or low-speed card at 10 char/sec.	Voice Channel at 300 char/sec.	I/O Device limited by 30:1 factor
High-speed paper tape or card at 150 char/sec.	Voice Channel at 300 char/sec.	Balanced
Incremental or variable-speed magnetic tape at 200 char/sec.	Voice Channel at 300 char/sec.	Balanced
High-speed magnetic tape at 60K char/sec.	Voice Channel at 300 char/sec.	Voice Channel limited by 20:1 factor
High-speed magnetic tape at 60K char/sec.	Broad-band Channel	Balanced

operate. Note carefully that this comparison uses nominal values for transmission speed of a group of devices or a type of communications facility. Actual speeds exhibit a considerable range.

Data Terminals, Inquiry Response

The inquiry-response data terminal serves the broad class of requirements where the amount of data transmitted is small and the operational efficiency of the terminal station is an important factor. Many important data communications applications require that the remote user of the system be able to ask a few very specific short questions and obtain a prompt reply in the form of a short message whose format is extremely restricted. There is no technical reason why these terminal requirements cannot be met by use of block-by-block terminals but operational and economic reasons generally indicate the desirability of specialized terminal equipment.

Broadly speaking, the functional characteristics of inquiry response terminals are comparable to those of block-by-block terminals. The principal areas of distinction are listed below.

1. The inquiry response terminal is not intended to store messages of any significant size.
2. Entry of information is usually from a manually-operated keyboard or card insertion station.
3. Display of information is generally restricted to a short message, a momentary display, or just a simple acknowledgement signal.
4. The entry and display mechanisms are highly tailored to the specific application. Their design, furthermore, minimizes operator training requirements and attempts to preclude operator errors from affecting a transmission. The operator rarely has control over message formats.
5. These terminals characteristically place low-duty cycle loads on communications lines. It is often economical to operate several of them through a common control unit which provides buffering and multiplexing functions between the group of terminals and the communications line to the central processor of the system.

Specific manifestations of these distinct requirements are reflected in products whose designs will next be discussed. Consider, for example, industrial data collection terminals. These terminals normally contain a combination of several basic data entry stations:

1. A manually inserted punched card reader;
2. A set of switches or pull-down levers which are set by the operator;
3. A switch set by the operator to indicate what type of message is to be sent;
4. A manually-inserted badge or token reader.

Operation of such a station is no more difficult than operation of a time-clock. The employee merely sets up the switches, inserts the card or badge, and presses a "Transmit" button. Except for the possibility of his setting up invalid combinations of data on the switches, the operator cannot control the message format or content, hence the system is fairly fool-proof. The only response given to the operator of such a terminal is a signal light indicating whether or not his message has been successfully received at the central collection point. If the message is rejected, he simply checks the controls and presses the "Transmit" button again.

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The economics of the industrial data collection system generally dictate multiplexing many terminals onto a single computer input line. The communications problem is much like that of the conventional home-telephone in that there may be delays in obtaining access to the line. The operator must at least know that his message may have to wait a few seconds to be picked up by the computer, but otherwise may be completely ignorant of the nature of the communication.

This example of the industrial data collection system generally typifies the inquiry-response terminal product group. In on-line banking, for example, the terminal keyboard looks, for all practical purposes, like a conventional accounting machine with a few extra keys. All functions are called out by keys that cause execution of exactly-specified operations. Elaborate features are provided to meet the protective requirements of the banking field. The teller's inquiry consists of keystroking a potential entry to a customer's account and the central computer's response consists essentially of permission to make the entry plus possibly the printing out of supplementary information on the account obtained from central records not accessible to the teller. The response is locked into the terminal system so that the teller not only has no choice about accepting it, but may not even appreciate what has happened.

The high degree of specialization indicated in the examples just cited is characteristic of this product group but not to the exclusion of more flexible general-purpose terminals. The CRT-keyboard terminal is easily adaptable to inquiry applications. The keyboard can accept alphanumeric information as well as special function codes. The CRT, even if restricted to an alphanumeric display on a fixed array of lines, can still present nicely formatted and captioned replies that are easily understood by the relatively untrained user.

The CRT-keyboard terminal provides flexibility but its costs are still rather high for modest applications. For applications where lowest cost is required and low data rates are sufficient, there exist very simple alphanumeric terminals that provide combinations of keyboard, printer, and manual card reader. These terminals often make clever use of the touch-tone dialing system now being phased into national use by the Bell System. The ultimate system of this type is the audio response system as it uses nothing but a touch-tone telephone for the terminal and a single time-shared audio response unit to compose the replies and steer them in audible form onto the proper telephone line.

The charts at the end of this section present listings of inquiry-response data terminals currently on the market. These terminals are generally grouped in accordance with their I/O mechanization. Two of the groups are for the flexible type of terminal while the others include terminals for specialized fields. Although audio-response terminals have been discussed here, no listing is provided because the terminal, per se, is a touch-tone telephone. The audio-response unit is discussed under the heading of special communications processors.

As shown in the charts, the input and output mechanisms for inquiry-response terminals are characteristically different from each other (keyboard for input vs CRT for output) whereas these mechanisms are either identical (magnetic tape) or highly com-

plementary (paper tape) in block-by-block terminals.

As has been previously indicated, terminals of this type frequently operate in a system where there is a multiplexing device that concentrates the data into a single channel to a central computer. Such devices are often special purpose, and tailored to particular terminal systems, but they are not listed with the terminals in this section, but rather under the heading of special communications processors.

Special Communications Processors

GENERAL PRODUCT CHARACTERISTICS

In data communications systems today, central processing and control functions are most frequently handled by a stored-program computer system. In most cases these requirements can be met economically by use of a general-purpose digital computer equipped with a product-line communications interface sub-system. Such systems, while of prime importance to the data communication system designer, are beyond the scope of this section, however, they are described in the section on general-purpose digital computers.

Although the use of general-purpose digital computers is quite broad, there are a few control problems that are best handled by special processing equipment due to either obvious functional requirements or economic considerations. There are, furthermore, some products whose inclusion is valuable from an educational viewpoint even if they may have been supplanted by more modern equipment. The equipment discussed and tabulated in this section generally meets the following criteria: highly specialized function, economic advantage due to special features, and educational interest even if possibly no longer competitive.

Communications Switching / Buffering Processors

The technical problems arising out of the computer-communications interface have intrigued system and logic designers from the days of the first such system (probably SAGE) to the present. Most of the early computer-communications systems were large and complex and consequently presented designers with significant opportunities to develop products whose design was optimum for a particular project. As the cost of logic was then roughly ten times what it is now, and core memories were one-tenth as fast, there were indeed good opportunities to achieve substantial savings through use of a clever combination of wired-logic and stored-program functions.

The techniques developed during these special-system optimization efforts were featured in a number of communications processors. These specialized machines contain features that are advantageous for handling the characteristic communications load with the attendant considerations such as:

1. Large number of low-speed channels;
2. Anticipated communications error rates expected;

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3. The required communications control procedures;
4. Requirement for handling 8-bit characters (before ASCII was adopted).

To minimize the cost of terminating a large number of low-speed channels, all of these machines generally employ bit-buffering. This technique saves considerable hardware but also utilizes a very large amount of high-speed memory time. To avoid "gagging" the machine with programmed bit-to-character operations, these machines all have special logic, which uses channel control words to perform the bit-to-character exchanges in usually three memory cycles per channel serviced.

The special switching computers generally have a separate mode for the bit-to-character operations. This mode operates either continuously, interlaced with normal program execution, or is entered periodically under program control. This communications mode is distinct from the mode under which conventional computer peripheral devices operate. These machines also generally utilized eight-bit characters well before ASCII or "third-generation computers".

It is well-established that communications programs required chained list data organization both within core memory and in the random-access file. Most applications have achieved this data design purely by program design. Two of these special processors, however, actually provide hardware features that somewhat relieve the programmer of this design task.

It is not clear what the role of these specialized machines will be in the future. They represent clever solutions to a problem at a time when specialized designs to save logic costs were often warranted but functionally, they do nothing that cannot be done by a general-purpose digital computer with a product-line communications interface. The current trend in the computer field toward mass-production of relatively standardized packages at prices inconceivable ten years ago probably makes the case for such special systems relatively weak.

REMOTE TERMINAL MULTIPLEXORS

Data communications system design problems frequently arise where a large number of low-duty-cycle devices require access to a central processing facility. To give each device a direct line is rather expensive. In these situations, it is frequently possible to obtain a significant cost savings by multiplexing groups of these devices into a single computer channel. A variety of remote terminal multiplexors has been developed within the industry to provide for these situations.

Remote terminal multiplexors generally are designed as an integral portion of a data system and cannot be used as independent devices. These devices do have many principles in common and their discussion as a class of products is useful as it illustrates these principles. A discussion of these devices and a tabular listing follow, but the use of this tabular listing should not imply that these devices can be individually selected and applied to any system.

There are four basic types of remote terminal multiplexors in use today.

1. Telephone Type

A telephone type multiplexor functions exactly like a telephone central. It selectively connects a large group of subscriber lines to a small number of trunks. The subscribers are scanned and may signal the multiplexor for a trunk connection, which is given if available. Multiplexing is accomplished on a call-by-call basis with no speed change.

2. Way Station

A way station multiplexor selectively gives access to a single communications line to subscribers who physically share the line. The multiplexor polls each subscriber in turn and gives it the line, if desired, for a single call. No speed change occurs.

3. Scanner-Speed Changer

This type of multiplexor combines data from a number of low-speed devices into a single high-speed channel of equivalent bandwidth. The data from the low-speed channels is interlaced onto the high-speed channel by a scanner which operates in the multiplexor to form "words" transmitted on the high-speed channel each of which contains a sample of information from all low-speed devices.

4. Display Console Control

This type of multiplexor receives alphanumeric command information from a central point and distributes it to a number of CRT displays. The control generally performs two information processing functions: conversion of data from command format to a display driving format, and driving the displays repetitively to maintain a flicker-free image. The amount of information sent to each display from the control often considerably exceeds the amount received by the control from the central computer, but in terms of useful information, a multiplexing function is provided.

AUDIO RESPONSE UNITS

The audio response unit is a device used to transmit programmable messages in spoken language. This type of equipment is normally controlled by a general-purpose computer and is used with remote terminals consisting of telephones equipped with touch-tone dialing capability to compose an inquiry-response system.

The remote subscriber obtains access to the computer through touch-tone dialing, and then further keys in a brief inquiry. The computer interprets the inquiry, processes it against master files, composes a reply and then creates a set of instructions to the audio response unit that causes it to issue the correct audible reply.

The audio response unit consists essentially of a rotating drum with many tracks. On each track is pre-recorded a standard word or phrase. Associated with each telephone line into the audio response unit is a bank of audio pickup heads, one per track. A message is programmed out of the audio response unit to a given telephone line by programming a sequence of drum revolutions during each of which a particular head is energized and connected to the telephone line.

EQUIPMENT CHARACTERISTICS REVIEW

The performance of an audio response unit is thus a function of the number of words in its vocabulary and the number of calls it can answer at the same time. Other limitations that exist are in the use of distinguishable vocabulary terms.

Communications Facilities and Modems

Communications facilities are normally chosen to provide data handling capacity based upon a traffic study. Although the communications engineer prefers to measure the capacity of a communications channel in bandwidth, in data communications applications it is much more natural to use bits/sec or char/sec as the measure. Of the two measures, bits/sec or baud is the more universal as character sizes vary between systems.

To achieve a desired transmission rate (in bits/sec) at a satisfactorily low error rate, it is necessary to specify not only bandwidth, but the line quality, the modem to be used, and the number of wires in the channel. The best way to see how these factors influence the choice of a facility is by examining a specific case.

Voice channels have a nominal bandwidth rating of 4 kHz. Several different quality voice channels are available. The differences lie in the actual achievable bandwidth, the smoothness of the amplitude vs frequency curve in the bandpass, and the delay vs frequency characteristic. The better characteristics of the higher quality channels permit use of modems with very high data transmission capabilities. The net effect of the combination of line quality and modem is illustrated below, using information furnished by Rixon Electronics Co.

AT & T Voice Channel Type (All channels are 4 kHz nominal)	Rixon Modem	Transmission
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4	Sebit-12M	1200 bits/sec
4A	Sebit-24M	2400 bits/sec
4B	Sebit-36M	3600 bits/sec
4C	Sebit-48M	4800 bits/sec

From this example it can be seen that achievement of a desired data rate on a communications facility requires careful engineering of the facility in combination with the modem.

The remaining consideration in communications facility choice is in the number of wires in the channel. A two-wire channel can support transmission only in one direction (except when special parallel-tone modems are used). The two-wire channel can, however, support transmission alternately in either direction. A four-wire channel can support transmission simultaneously in both directions at considerably less than twice the cost of a two-wire facility.

The choice between two-wire and four-wire facilities depends on the requirements for data transmission and acknowledgements. If a facility is to be used to transmit substantial quantities of data in both

directions, then the four-wire channel may be favored. If transmission is primarily unidirectional there still exists the problem of delays due to acknowledgements. All modern systems for data transmission use block-by-block acknowledgement procedures. On a two-wire line, the system must halt transmission after each block and wait for acknowledgement. If the transmission rates are high and the blocks short, the delay experienced in receipt of the acknowledgement may reduce the net achievable transmission rate.

The common carriers, American Telephone and Telegraph and Western Union, offer a wide variety of communications facilities both with and without modems. A brief listing of some of these offerings is provided in the charts that follow this section. The information in these charts gives a basic indication of the types of facilities available, but it is always best for the system designer to consult directly with common carrier technical representatives.

Several firms manufacture modems that the user can employ for direct connection to common carrier facilities. These modems are separately listed in one of the charts.

DATA TERMINALS, BLOCK-BY-BLOCK (HIGH-SPEED PRINTER TERMINALS)

MANUFACTURER	DATA PRODUCTS	DIGITRONICS
MODEL	—	D401
PRODUCT TYPE	Off-line magnetic tape-to-printer terminal	Medium-speed printer terminal
INPUT MECHANISMS	Magnetic tape	—
OUTPUT MECHANISMS	High-speed printer (360/1000-lines/min.)	Medium-speed printer (300 lines/min.)
FORMATS	Up to 512 char./block	—
DOCUMENT CHARACTERISTICS	120 or 132 char./line	120 or 132 char./line
CODES I/O Medium Transmission Medium	BCD 7 level	BCD
COMMUNICATION MEDIUM Channel Type Modem Required	Voice 201-A3 Modem	Voice Yes
TRANSMISSION Simultaneity Synchronization	Simplex Sync.	Half-duplex Async.
ERROR DETECTION Lateral/Longitudinal Corrective Action	Lateral Automatic retransmission	Lat./Long. Automatic retransmission
COMMENTS	Lower case characters available	

DATA TERMINALS, BLOCK-BY-BLOCK (TELEPRINTERS)

MANUFACTURER	FRIDEN	IBM	TELETYPE	TELETYPE
MODEL	2201 Flexowriter	1050	32/33	35
INPUT MECHANISMS	Keyboard Paper tape reader Card reader	Paper tape reader Card reader	Keyboard Paper tape reader (optional)	Keyboard Paper tape reader
OUTPUT MECHANISMS	Page printer Paper tape punch Edge-punched cards	Paper tape punch Edge-punch cards Card punch	Page printer Paper tape punch (optional)	Page printer Paper tape punch
FORMATS	Buffered block transmission	51/80 col. cards	72 char. line width (max.)	72 char. line width (max.)
DOCUMENT CHARACTERISTICS	Various size platen	8 1/2" wide paper	8 1/2" wide paper 1 paper tape	8 1/2" wide paper 1 paper tape
CODES	I/O Medium Transmission Medium	N/A	5 level (Model 32) 8 level ASCII	Any 8 level
			5 level (Model 32) 8 level ASCII	Any 8 level
TRANSMISSION	Speed Simultaneity Synchronization	15 char/sec Half-duplex Async.	10-15 char/sec	6-10 char/sec
			Half- or full duplex	Half- or full duplex
			Async.	Async.
ERROR DETECTION	Lateral/Longitudinal Corrective Action	Lat./Long.	None (Model 32) Lateral (Even)	Lateral (Even)
			Automatic retransmission Delete Repunch	Manual retransmission
COMMENTS			Pin-feed paper Also available; 12 char. per inch printing	Pin-feed paper standard; Friction feed available

DATA TERMINALS, BLOCK-BY-BLOCK (PAPER TAPE TERMINALS)

MANUFACTURER	DIGITRONICS	FRIDEN	FRIDEN	G. E. COMPUTER DEPT.	G. E. PRINTER- READER SECTION	RCA	TALLY CORP.	TALLY CORP.
MODEL	D507/509	Teledata	Dual Teledata	Datanet 600	Omni-data 2400	5903	100 Series	200 Series
INPUT MECHANISMS	Paper tape reader	Paper tape reader	Paper tape reader	Paper tape reader	Paper tape reader	Paper tape reader	Paper tape reader	N/A
OUTPUT MECHANISMS	Paper tape punch	Paper tape punch	Paper tape punch	Paper tape punch	Paper tape punch	Paper tape punch	N/A	Paper tape punch
DOCUMENT CHARACTERISTICS	—	—	—	11/16", 7/8", 1" tape	—	11/16", 7/8", 1" tape	30-720 char. per block (Models 111, 128)	30-720 char. per block (Models 211, 228)
CODES	I/O Medium Transmission Medium	5, 6, 7, or 8 level 5, 7 (BCD), or 8 level (ASCII)	Any 8 level	Any 5, 6, 7, or 8 level	8 level ASCII	Any 5, 6, 7, or 8 level	Any 5 or 8 level	Any 5 or 8 level
COMMUNICATION MEDIUM	Channel Type Modem Required	Voice	Teleprinter	Voice	Teleprinter	Voice	Voice	Voice
TRANSMISSION Speed	100/150 char/sec	5-10 char/sec	14 char/sec	50 char/sec	10/150 char/sec	100 char/sec	60/72/120 char/sec	60/72/120 char/sec
Simultaneity	Half-duplex	Half-or full duplex	Half-or full duplex	Half-duplex	—	Half-duplex	—	—
Synchronization	Sync.	Sync.	Sync.	Async.	—	—	Serial or parallel	Serial or parallel
ERROR DETECTION	Lat./Long.	Lateral	Lateral	Full character redundancy	Lateral	Lat./Long.	Lateral (Models 111, 128 only)	Lateral (Models 211, 228 only)
Other								
Corrective Action	Automatic retransmission	Manual retransmission	Manual retransmission	Automatic retransmission	Automatic retransmission	Manual retransmission	Retransmission of last block (111, 128)	Punches flag character

DATA TERMINALS, BLOCK-BY-BLOCK (PAPER TAPE TERMINALS) (Cont'd.)

MANUFACTURER	TALLY CORP.	TALLY CORP.	TELETYPE CORP.	TELETYPE CORP.	TELETYPE CORP.	TELETYPE CORP.	TELETYPE CORP.
MODEL	300/301	700	DRPE	CX and DX	1050	750	1200 EDC
INPUT MECHANISMS	Paper tape reader	Paper tape reader Magnetic tape	N/A	Paper tape reader	Paper tape reader	Paper tape reader	Paper tape reader
OUTPUT MECHANISMS	Paper tape punch	Paper tape punch Magnetic tape	Paper tape punch	N/A	Paper tape punch	Paper tape punch	Paper tape punch
DOCUMENT CHARACTERISTICS	ASA	Adjustable record length	11/16", 7/8", 1" tape	11/16", 1" tape (receiving), 11/16", 7/8" 1" (sending)	11/16", 1" tape	11/16", 7/8", 1" tape	80 char blocks, 3/4" 11/16", 1" tape
CODES	I/O Medium		Any 5 or 8 level	Any 5, 6, 7, or 8 level	Any 5, 6, 7, or 8 level	Any 5, 6, 7, or 8 level	Any 5, 6, 7, or 8 level
	Transmission Medium		Any 5 or 8 level	Any 5, 6, 7, or 8 level	Any 5, 6, 7, or 8 level	Any 5, 6, 7, or 8 level	Any 5, 6, 7, or 8 level
COMMUNICATION MEDIUM	Channel Type		Voice	Voice	Voice	2-Voice	2-Voice
Modem Required	202C Modem		Yes	Yes	Yes	Yes	Yes
TRANSMISSION Speed	60 char/sec (300) 120 char/sec (301)	60 to 120 char/sec	Up to 240 char/sec	240 (DX), 105 (CX) char/sec	105 char/sec	75 char/sec	150/120 char/sec
Simultaneity	Half-duplex	Half-duplex	Receive-only	—	Half-or full duplex	Half-or full duplex	Half-or full duplex
Synchronization	Serial (301) Parallel (300)	Serial or parallel	Async.	—	Async.	Async.	Async.
ERROR DETECTION	Lateral/Longitudinal		None	None	None	None	Two check characters
Other Corrective Action	None	Automatic retransmission	None	None	None	None	Retransmission Overpunching

DATA TERMINALS, BLOCK-BY-BLOCK (PUNCHED CARD TERMINALS)

MANUFACTURER	DATRON SYSTEMS	DIGITRONICS	IBM	IBM	SYSTEMATICS Div. of Gen. Instr.	
MODEL	610	D512	1013	65/66	T981	
INPUT MECHANISMS	Keyboard (optional) Card reader	Card reader	Card reader	Card reader	Keyboard Card reader	
OUTPUT MECHANISMS	—	—	Card punch	Card punch	Page printer	
FORMATS	51 or 80 col. cards	80 col. cards	80 col. cards	80 col. cards	80 col. cards	
CODES	I/O Medium		BCD	Hollerith	Hollerith	BCD
	Transmission Medium		—	7 level	4 out of 8	4 out of 8
COMMUNICATION MEDIUM	Channel Type		Voice	Voice	Teleprinter	Teleprinter
Modem Required	Yes	201B Modem	Yes	Yes	Yes	Yes
TRANSMISSION Speed	10 char/sec	75 cards/min.	75/150/250/300 char/sec	10-15 char/sec	10/12/15 char/sec	
Simultaneity	—	Half-duplex	Half-or full duplex	Half-duplex	Half-or full duplex	
Synchronization	—	Sync.	Sync.	Sync.	Sync.	Async.
ERROR DETECTION	Lateral/Longitudinal		Lat/Long	—	Lateral	—
Other	—	Block count	4 out of 8	—	Bit count sent end of each card	
Corrective Action	Manual retransmission	Automatic retransmission	Automatic retransmission	Manual retransmission	None	
COMMENTS	A module of the Dial-O-verter system				Used with a Teletype unit	

DATA TERMINALS, BLOCK-BY-BLOCK (MAGNETIC TAPE TERMINALS)

MANUFACTURER	CONTROL DATA	DIGITRONICS	IBM	IBM	RCA	ULTRONIC SYSTEMS
MODEL	8031	D522	7701/7702	7711	5907	MT 3000
I/O MECHANISMS	Magnetic tape	Magnetic tape	Magnetic tape	Magnetic tape	Magnetic tape	Magnetic tape
FORMATS	—	7 or 9 channel IBM tapes	200 bpi, 7 channel 1/2" tape	7 channel 1/2" tape	128/256 char/block IBM 1/2" tape	7 or 9 channel IBM tapes
CODES I/O Medium	—	BCD	BCD	BCD	BCD	BCD
Transmission Medium	—	BCD-8 level	4 out of 8	4 out of 8	—	—
COMMUNICATION MEDIUM Channel Type	Voice	Voice	Voice	Voice	Voice	Voice
Modem Required	201A Modem	Yes	Yes	Yes	Yes	Yes
TRANSMISSION Speed	250/300 char/sec	300/36,000 char/sec	75/150 char/sec (7701) 150/250/300 char/sec (7702)	150/28,800 char/sec	150/300/66,000 char/sec	150/300/450 600/5100 char/sec
Simultaneity	—	Half-duplex	Half-duplex	Half-duplex	Half or full duplex	Half-duplex
Synchronization	—	Sync.	Sync.	—	—	Sync./Async.
ERROR DETECTION Lateral/Longitudinal	Lat./Long.	Lat./Long.	—	—	Lat./Long.	Lat./Long.
Other		Block count	4 out of 8	4 out of 8		
Corrective Action	Automatic retransmission	Automatic retransmission	Automatic retransmission	Automatic retransmission	Automatic retransmission	Automatic retransmission
COMMENTS		A module of the Dial-o-verter system				

DATA TERMINALS, BLOCK-BY-BLOCK (MULTI-DEVICE TERMINALS)

MANUFACTURER	DIGITRONICS	HONEYWELL	TALLY CORP.	UNIVAC
MODEL	500 Series	EDP Data Station	311	1004
INPUT MECHANISMS	Paper tape reader Card reader Magnetic tape	Optical scanner Paper tape reader Keyboard Punched cards	Typewriter Paper tape reader Card reader	Paper tape reader Card reader Magnetic tape
OUTPUT MECHANISMS	Paper tape punch Line printer Magnetic tape	Paper tape punch Page printer	Paper tape punch Typewriter	Paper tape punch Line printer Magnetic tape
FORMATS	—	132 char/block	30-720 char/block	—
CODES I/O Medium	—	8 level ASCII	—	—
Transmission Medium	8 level	8 level ASCII	Any 5 or 8 level	Any 5, 6, 7, or 8 level
COMMUNICATION MEDIUM Channel Type	Voice	Voice	Voice	Voice
Modem Required	Yes	Yes	Yes	Yes
TRANSMISSION Speed	Up to 5100 char/sec	120 char/sec	120 char/sec	240-342 char/sec
Simultaneity	Half-duplex	Half-duplex	Half-duplex	—
Synchronization	Sync.	Serial	Serial	—
ERROR DETECTION Lateral/Longitudinal	Lat./Long.	Lat./Long.	Lateral	Lat./Long.
Corrective Action	Automatic retransmission	Automatic retransmission	Automatic retransmission	Automatic retransmission

DATA TERMINALS, BLOCK-BY-BLOCK (MISCELLANEOUS)

MANUFACTURER	DARTEX	MOHAWK DATA SCIENCES	RADIO ELECTRONICS CORP.	SYSTEMATICS Div. of Gen. Instr.
MODEL	Data Terminal	1102/3/4/6/8	Community type	T585/T588
INPUT MECHANISMS	Keyboard Magnetic tape Paper tape reader Card reader (optional)	Keyboard (off-line) Magnetic tape Card reader (optional)	Keyboard (off-line) Magnetic tape	Keyboard Paper tape reader Card reader
OUTPUT MECHANISMS	Magnetic tape	Magnetic tape Page printer (off-line)	Magnetic tape Page printer (off-line)	Card punch Paper tape punch Page printer
PRODUCT TYPE	Data recorder and transmitter	Data recorder and transmitter	Data recorder and transmitter	—
FORMATS	Blocked 1/4" magnetic tape	Blocked 1/2" magnetic tape	Blocked 1/2" interword gap	80 col. cards
DOCUMENT CHARACTERISTICS	120,000 characters on magnetic tape	—	30,000 characters on magnetic tape	—
CODES I/O Medium	—	—	—	BCD
Transmission Medium	Any 8 level	8 level	8 level	5 level (T585) 6, 7, or 8 level (T588)
COMMUNICATION MEDIUM Channel Type	Voice	Voice	Voice	Teleprinter
Modem Required	Yes	Yes	Yes	Yes
TRANSMISSION Speed	120/1600 char/sec	100/120 char/sec	100 char/sec	10/12/15 char/sec
Simultaneity	—	—	—	Half or full duplex
Synchronization	Async.	—	—	Async.
ERROR DETECTION Lateral/Longitudinal	Lateral	Lateral	Lateral	Lateral
Other	Complement redundancy	Bit count at end of message	—	—
Corrective Action	—	Retype Manual retransmission	Retype	Manual retransmission
COMMENTS		Uses a permanent magnetic tape buffer for sending and receiving	Keyboard input recorded on permanent magnetic tape loop	Operates with IBM card punch and Teletype unit

DATA TERMINALS, INQUIRY-RESPONSE (INDUSTRIAL DATA COLLECTION TERMINALS)

MANUFACTURER	CONTROL DATA	FRIDEN	IBM	IBM	RCA
MODEL	8010	Collectdata 30	357	1030	6201
DOCUMENT INPUT	30 to 80 col. card	80 col. card 10 col. badge	80 col. card 10 col. badge	80 col. card 10 col. badge	80 col. card 12 col. badge
VARIABLE INPUT	9 col. numeric	10 col. numeric	12 col. numeric 1 manual 2 cartridge	12 col. numeric 1 manual 2 cartridge	10 col. numeric
OUTPUT OR COLLECTION DEVICES	8092 teleprogrammer (computer)	Computer or paper tape punch	024/26 keypunch	Computer or punch card	Computer or paper tape punch
TRANSMISSION CHARACTERISTICS Speed	60 char/sec	30 char/sec	20 char/sec	60 char/sec	27.7 char/sec
Cable	48 wire	2 or 13 wire	2 or 39 wire	2 or 32 wire	2 or 4 wire
Max. Dist.	8500 ft.	2 miles	5000 ft.	9 miles	13 miles
ERROR DETECTION Lateral/Longitudinal	Parity	Parity	None	Parity	Parity
Other	Message length	Message length	Message length	Message length	Message length
Corrective Action	Reject message	Manual retransmission	None	—	Reject message

DATA TERMINALS, INQUIRY-RESPONSE (CRT TERMINALS)

MANUFACTURER	BOLT, BERANEK AND NEWMAN	BUNKER-RAMO	BUNKER-RAMO	CONTROL DATA	CONTROL DATA	G. E. COMPUTER DEPT.
MODEL	TELEPUTER	200 SERIES	400 SERIES	210	Remote Conversational Console	Datnet 760
DISPLAY STORAGE (NO. OF CHARACTERS)	—	32 to 768 (delay line)	384	1000	1000	1196 (delay line)
SCREEN SIZE	5" x 5"	4 1/2" x 3 1/2" 7" x 5"	7-3/4" x 5-5/8"	6" x 8"	6" x 8"	7" x 9-1/3"
TRANSMISSION Speed	2400 bit/sec.	240 char/sec	—	240 char/sec	240 char/sec	1200 bit/sec (async.) 2400 bit/sec. (sync)
Simultaneity	Full-duplex	Half-duplex	Half-duplex	—	—	Half-duplex
Synchronization	Sync.	Async.	—	—	—	Async. or sync.
ERROR DETECTION	Parity	Yes	—	Parity	Parity	Parity
CODES	Any code	ASCII	—	—	—	ASCII
EDITING	Partial	Full cursor	Full cursor	Full cursor	—	Full cursor
DIRECT COMPUTER TRANS. RATE	—	—	—	50,000 char/sec	50,000 char/sec	—
CHARACTER SCREEN FORMATS	—	2 lines of 16 to 12 lines of 64 char.	12 lines of 32 char.	20 lines of 50 char.	20 lines of 50 char.	26 lines of 46 char.
REGENERATION	—	42 times per sec.	—	50 times per sec.	50 times per sec.	—
CONTROLS	None	Brightness Focus Character height	Brightness Focus Character height	—	—	—
ALTERNATE OUTPUT	Teleprinter	Yes	No	—	Card reader Page printer	Teleprinter
SPECIAL FEATURES	Math. functions	—	Alternate input (paper tape)	Self-contained buffer time-shares control	—	Flashing

DATA TERMINALS, INQUIRY-RESPONSE (SMALL KEYBOARD PRINTER, CARD READER TERMINALS)

MANUFACTURER	DATA TRENDS	DATA TRENDS	DIGITRONICS	IBM	RIXON
MODEL	Mimo	TP10	Data-Verter 800 Series	1001	Data message composer
INPUT MECHANISMS	Special keyboard	Touch tone telephone	Adding machine	Punched card Keyboard	Vertical dials
OUTPUT MECHANISMS	Printed paper tape indicators	Strip printer	Paper tape terminal, magnetic tape	26 punched card unit or audio unit	Indicators
DOCUMENT CHARACTERISTICS	5x7 matrix strip printer	—	—	21/51/80 col. card	—
CODES I/O Medium	ASCII	—	—	BCD	5 level
Transmission Medium	ASCII	—	—	—	5 level
COMMUNICATION MEDIUM Channel Type Modem Required	Teleprinter	Voice	Voice 202C Modem	Voice 401A Modem	Teleprinter
TRANSMISSION Speed	10 char/sec	10 char/sec	27/36 char/sec	12 char/sec	10 char/sec
Simultaneity	Half-duplex	Simplex	Simplex	—	Simplex
Synchronization	Async. serial	—	Serial by bit	—	—
ERROR DETECTION Lateral/Longitudinal	—	—	Parity	Parity	—
Other	—	—	—	Field Length	—
Corrective Action	—	—	Manual	Manual	—

DATA TERMINALS, INQUIRY-RESPONSE (CRT TERMINALS) (Cont'd.)

MANUFACTURER	GEOSPACE	HENDRIX WIRE AND CABLE	HONEYWELL	IBM	RCA	SANDERS ASSOC.
MODEL	SAND	5100	VIP	1015/1016	6051/6052	720
DISPLAY STORAGE (NO. OF CHARACTERS)	1040	—	384/768/5376	1200	480	256/512/1024 (delay line)
SCREEN SIZE	8" x 23"	6" x 8"	4-3/4" x 3-3/4" to 7-3/4" x 5-1/2"	5" x 5"	7" x 9-1/3"	7-1/2" x 9-1/2"
TRANSMISSION Speed	26,000 char/sec	2400 bit/sec	1200/2400 bit/sec	650 char/sec.	105/180/10 char/sec	110/1200/1800 (async.) 2000/2400 (sync.) bit/sec
Simultaneity	Half-duplex	Half-duplex	Half-duplex	Half-duplex	Half-duplex	—
Synchronization	Sync.	Async.	Serial async.	—	—	Sync. or async.
ERROR DETECTION	Parity	Parity	Parity	Parity	Parity	Parity
CODES	Any 6, 7, or 8 level	ASCII	ASCII	6 bit	—	ASCII
EDITING	Full cursor	Full cursor	Partial cursor	Full cursor	Full cursor	Partial or full cursor
DIRECT COMPUTER TRANS. RATE	—	—	—	—	—	47,500 char./sec. (parallel)
CHARACTER SCREEN FORMATS	Up to 36 lines	13 lines of 80 char.	2 lines of 16 to 12 lines of 64 char.	30 lines of 40 char.	—	40 lines of 52 or 32 lines of 64 char.
REGENERATION	—	—	40 times per sec.	—	—	46.5 times per sec.
CONTROLS	None	None	Brightness Focus Character size	—	—	Brightness Focus Character size, page size
ALTERNATE OUTPUT	—	Page printer	—	No	—	Teleprinter
SPECIAL FEATURES						Character tilt

STORED-PROGRAM COMMUNICATIONS SWITCHING/BUFFERING PROCESSORS

DATA TERMINALS, INQUIRY-RESPONSE (SPECIAL ON-LINE TELLER SYSTEMS)

MANUFACTURER	Burroughs	NCR
MODEL	—	42-501
INPUT MECHANISMS	Keyboard	Keyboard
OUTPUT MECHANISMS	Page printer Indicators	Page printer Indicators
CODES I/O Medium	5-level	—
COMMUNICATION MEDIUM		
Channel Type	Voice	Voice
Modem Required	Yes	Yes
TRANSMISSION Speed	167 char/sec	300 char/sec
Simultaneity	Full-duplex	Full-duplex
Synchronization	Async.	—
ERROR DETECTION		
Longitudinal/Lateral	Yes	Yes
Other	No	Yes
Corrective Action	Yes	Manual retransmission

MANUFACTURER	COLLINS	G. E. Computer Dept.	IBM	IBM
MODEL	C-8400	Datanet-30	7740	7750
PRODUCT TYPE	Communications processor	Communications processor	Communications control system	Programmed transmission control
MEMORY Cycle time	5 usec.	7 usec.	10 usec.	28 usec.
Word Length	16 bits	18 bits	32 bits	48 bits
Max. Capacity	65k	16k	16k	16k
BUFFERS				
Low-speed type (up to 180 baud)	Bit	Bit	Bit	Bit
Low-speed number	256	120	84	112
High-speed type (up to 2400 baud)	Char.	Char.	Char.	Char.
High-speed number	Up to 6	Up to 6	Up to 6	Up to 6
CHANNEL SERVICE MODE	Enter under program control	Enter under program control	Interlaced	Interlaced
OTHER COMPUTER INTERFACE	Yes	Yes	Yes	Yes
HANDLES CONVENTIONAL PERIPHERAL DEVICES	Yes	Yes	Yes	No
COMMENTS	Separate control memory 1k, 36-bit word, 1 usec, stored logic machine		4 interlaced modes of operation, programmed + automatic mode switching	Separate control memory, 128 words, 48 bits, 12 usec

REMOTE TERMINAL MULTIPLEXORS

MANUFACTURER	Burroughs HS	CONTROL DATA	DATA TRENDS	G.E. COMPUTER DEPT.	IBM	IBM	IBM
MODEL	Teller System	8012, 8013	MIMO	Datanet 3101	2712	358	1034
PRODUCT TYPE	Remote terminal unit	Multiplexor	Multiplexor	Accumulator	Remote multiplexor	Station control	Punch
TYPE OF MULTIPLEXOR	Telephone	Telephone	Telephone	Telephone	Scanner,speed changer	Telephone	Way station
LOW-SPEED DEVICE Type of Device	On-line teller system	CDC 8011 collector	Inquiry-response terminal	Datanet 3101 collector	IBM 1050, 1060, 2740, 2741 terminals	IBM 357 input station	IBM 1031 input station
Number	Up to 96	Up to 16	Up to 100	Up to 10	10 or 14	Up to 20	Up to 24
Data Rate	167 char/sec	54 char/sec	10 char/sec	60 char/sec	75 or 135 bit/sec.	Up to 20 char/sec	60 char/sec
HIGH-SPEED DEVICE Type of Interface	Remote terminal to central terminal	Input line to CDC 8092 computer	—	Paper tape punch	Voice channel	Punched card output station	Punched card
Data Rate	167 char/sec	54 char/sec	—	110 char/sec	1125 or 1485 bit/sec	Up to 20 char/sec	60 char/sec

REMOTE TERMINAL MULTIPLEXORS (Cont'd.)

MANUFACTURER	IBM	Lenkurt	RCA	RCA	Sanders Assoc.	Ultronics Systems
MODEL	2848	25A	70/356	6235-3	720	CM2000
PRODUCT TYPE	Display control	Multiplexor	Communications line switch adapter	Edge line concentrator	Control unit	Character multiplexor
TYPE OF MULTIPLEXOR	Display console control	Telephone	Telephone	Telephone	Telephone	Scanner speed changer
LOW-SPEED DEVICE Type of Device	IBM2260 displays IBM 1053 printer	Telegraph multiplexor	Edge collector or teleprinter	Edge data collector	Display console control	Teletype
Number	Up to 24 displays	Up to 25	Up to 12	Up to 25	Up to 12	Up to 20
Data Rate	Video signals at very high rates	Up to 200 bit/sec.	27.7 char/sec	27.7 char/sec	110 to 2400 bit/sec.	30 char/sec
HIGH-SPEED DEVICE Type of Interface	System/360 channel or data line	—	Up to 2 computer input lines	Up to 4 lines to edge buffers	I/O direct to computer	Voice channel
Data Rate	Up to 2400 bit/sec.	—	27.7 char/sec	27.7 char/sec	47,500 char/sec	4800 bit/sec.

AUDIO RESPONSE UNITS

MANUFACTURER	IBM	IBM	IBM	IBM	RCA	RCA	RCA
Model	7770-1	7770-2	7770-3	7772	70/510-11	70/510-21	70/510-26
NO. OF VOCABULARY WORDS	Up to 126	Up to 127	Up to 128	Unlimited	31 phrases 93 words	63 phrases 63 words	189 words
TIME PERIOD FOR WORD	0.5 sec	0.5 sec	0.5 sec	1 sec	0.5 sec word 1.5 sec phrase	0.5 sec word 1.5 sec phrase	0.5 sec word
NO. OF SIMULTANEOUS CALLS	Up to 48	Up to 48	Up to 48	Up to 8	Up to 50	Up to 50	Up to 50
MAX. MESSAGE LENGTH TRANSMITTED	34 to 38 words	39 words	Indefinite	Indefinite	—	—	—
MAX. INQUIRY LENGTH	36 char. to 40 char.	40 char	Indefinite	Indefinite	—	—	—

MODULATORS-DEMODULATORS (MODEMS)

MANUFACTURER	MODEL	SPEED	SERIAL OR PARALLEL	CHANNEL TYPE	NO. OF WIRES	SYNC. OR ASYNC.	SIMPLEX OR DUPLEX	PRIVATE LINE MANDATORY?	AUTO. CALL UNIT	COMMENTS
AUTOMATIC ELECTRIC	103C	—	—	Voice	—	—	Full	No	No	Alternate voice/data service
AUTOMATIC ELECTRIC	401A/E	20 char/sec	Parallel	Voice	—	Async.	Simplex	—	No	Transmit only
AUTOMATIC ELECTRIC	101A/C	10 char/sec	Serial	TWX	—	Async	Simplex Half/full	No	No	Used with Teletype 33 & 35
BELL SYSTEM	103A	200 bit/sec	Serial	Voice	2	Async.	Half/full	No	Yes	
BELL SYSTEM	103B	200 bit/sec	Serial	Voice	2	Async.	Half/full	Yes	No	
BELL SYSTEM	103F	300 bit/sec	Serial	Voice	2	Async.	Half/full	No	No	
BELL SYSTEM	201A3	2000 bit/sec	Serial	Voice	2/4	Sync.	Full on 4 wire	No	Yes	No voice comm.; replacing 201A1
BELL SYSTEM	201A4	2000 bit/sec	Serial	Voice	2/4	Sync	Full on 4 wire	No	Yes	No voice comm.; replacing 201A2
BELL SYSTEM	201B1	2400/bit/sec	Serial	Voice	2/4	Sync.	Full on 4 wire	Yes	No	No voice comm.
BELL SYSTEM	201B2	2400 bit/sec	Serial	Voice	2/4	Sync.	Full on 4 wire	Yes	No	No voice comm.
BELL SYSTEM	202A	1200 bit/sec	Serial	Voice	2	Async	Half	No	No	
BELL SYSTEM	202B	1800 bit/sec	Serial	Voice	2/4	Async.	Full on 4 wire	Yes	No	
BELL SYSTEM	202C	1200 bit/sec	Serial	Voice	2	Async.	Half	No	Yes	Replacing 202A
BELL SYSTEM	202D	1800 bit/sec	Serial	Voice	2/4	Async.	Full on 4 wire	Yes	Yes	No voice comm.; replacing 202B
BELL SYSTEM	X202E	600 bit/sec	Serial	Voice	2	Async.	Full	No	No	
BELL SYSTEM	301B	40,800 bit/sec	Serial	Voice	—	Sync.	Full (voice)	No	No	Sync. mechanism can be external
BELL SYSTEM	303	19,200/50,000/230,400 bit/sec.	Serial			Sync./ Async.	Full (voice)	No	No	
BELL SYSTEM	401A	20 char/sec	Parallel	Voice	2	Async.	Simplex Full (voice)	No	No	Transmit only; 24 possible characters
BELL SYSTEM	401E	20 char/sec	Parallel	Voice	2	Async.	Simplex Full (voice)	No	No	Transmit only; 99 possible characters
BELL SYSTEM	401J	20 char/sec	Parallel	Voice	2	Async.	Simplex	No	Yes	Receive only; 99 possible characters
BELL SYSTEM	401H	20 char/sec	Parallel	Voice	2	Async.	Simplex	No	No	Transmit only; 99 possible characters
BELL SYSTEM	X401L	20 char/sec	Parallel	Voice	2	Async.	Simplex	No	Yes	Transmit only
BELL SYSTEM	X202F	600 bit/sec	Serial	Voice	2	Async.	Simplex	No	Yes	Transmit only
BELL SYSTEM	402C	75 char/sec	Parallel	Voice	2/4	Async.	Simplex	No	Yes	Transmit only
BELL SYSTEM	402D	75 char/sec	Parallel	Voice	2/4	Async.	Simplex	No	Yes	Receive only
BELL SYSTEM	X403A	10 char/sec	Parallel	Voice	—	—	Simplex	No	Yes	Touch tone; receive only
BELL SYSTEM	X403B&C	10 char/sec	Parallel	Voice	—	—	Simplex	No	Yes	Touch tone; transmit only
BELL SYSTEM	602A	—	—	Voice	2	Sync.	Simplex	No	No	Analog transmitter
BELL SYSTEM	603A, B&D	—	—	Voice	—	—		No	No	Analog facsimile transmitter
BELL SYSTEM	801A&C	N/A	Serial/ Parallel	Voice/TWX	2/4	Async./ Sync.	Simplex Half or Full	N/A	N/A	Automatic calling units
BELL SYSTEM	811B	10 char/sec	Serial	TWX	2	Async.	Simplex Half or Full	No	Yes	Used with Teletype units

MODULATORS-DEMODULATORS (MODEMS) (Cont'd.)

MANUFACTURER	MODEL	SPEED	SERIAL OR PARALLEL	CHANNEL TYPE	NO. OF WIRES	SYNC. OR ASYNC.	SIMPLEX OR DUPLEX	PRIVATE LINE MANDATORY?	AUTO. CALL UNIT	COMMENTS
COLLINS RADIO	TE-210-D2	2400 bit/sec.	Serial	Voice	—	—	—	Yes	No	
COLLINS RADIO	TE-216-A	7600 bit/sec.	Serial	Voice	—	—	—	Yes	No	
COLLINS RADIO	TE-217-A	92,400 bit/sec.	Serial	Broadband	—	—	—	Yes	No	
COLLINS RADIO	TE-218-A	460,800 bit/sec.	Serial	Broadband	—	—	—	Yes	No	
IBM	Line Adapter 1		Serial	Voice	2/4	Async.	Half/full	No	No	Limited distance
IBM	Line Adapter 2	Up to 600 bit/sec.	Serial	Voice	2		Half	No	No	Limited distance
IBM	Leased Line	Up to 600 bit/sec.	Serial	Voice	2/4	—	Half/full	No	No	
IBM	Shared Line	Up to 134 bit/sec.	Serial	Voice	2/4	—	Half/full	No	No	
LENKURT ELECTRIC	26C	1200/2400 bit/sec.	Serial	Voice		Sync.		Yes	No	
PHILCO	MD/NY	1200/2400 bit/sec.	Serial	—	2/4	—	Half/full	Yes	—	High frequency radio modems
PHILCO	MC 12/24-2B	300 to 2400 bit/sec.	Serial	Voice	—	Sync.	Full	Yes	—	
PHILCO	MC 12/24-1	300 to 2400 bit/sec.	Serial	Voice	—	Sync.	Full	Yes	—	High frequency radio modems
PHILCO	Diplexer	75 bit/sec.	Serial	Voice	—	Sync./Async	Full	No	—	For sending Teletype/voice signal simultaneous
PHILCO	EDC 1224	75 to 2400 bit/sec.	Serial	—	—	Sync.	—	Yes	—	Increased error detection and correction
PHILCO	EDC 61-75	75 bit/sec.	Serial	Teleprinter	—	Sync.	Full	No	—	Increased error detection and correction
RIXON ELECTRONICS	SEBIT	600 to 4800 bit/sec.	Serial	Voice	—	Sync.	—	Yes	No	
RIXON ELECTRONICS	FM-12	1200 bit/sec.	—	—	—	Sync./ Async.	Simplex Half/full	—	No	
RIXON ELECTRONICS	SEBIT-48M	4800 bit/sec.	Serial	Voice	—	—	—	Yes	No	
WESTERN UNION	1181-A	180 bit/sec.	Serial	—	—	Async.	Half/full	No	No	
WESTERN UNION	1601-A	600 bit/sec.	Serial	Voice	—	Async.	Half/full	No	No	Alternate voice/ data option
WESTERN UNION	2121-A	1200 bit/sec.	Serial	Voice/broadband	—	Async.	Half/full	No	No	
WESTERN UNION	2241-A	2400 bit/sec.	Serial	Broadband	—	Sync./ Async	Half/full	Yes	No	
WESTERN UNION	100	200 bit/sec.	Serial	Voice	2/4	Async.	Half/full	No	No	
WESTERN UNION	200	2400 bit/sec.	Serial	Voice	2/4	Async.	Half/full	Yes	No	
WESTERN UNION	300	18,000/40,800 bit/sec	Serial	Broadband	2/4	Sync.	Half/full	No	No	

COMMON CARRIER TRANSMISSION FACILITIES

COMMON CARRIER	FACILITY DESCRIPTION	BAND RATE (BIT/SEC.)	MODEM USED	NO. OF VOICE CHANNELS REQUIRED	COMMENTS
AT&T	Schedule 1 Teleprinter channel	45	None	1/12	
AT&T	Schedule 2 Teleprinter channel	57	None	1/12	
AT&T	Schedule 3 Teleprinter channel	75	None	1/12	
AT&T	Schedule 3A Teleprinter channel	150	None	1/8	
AT&T	Schedule 4 Voice channel	2000	Bell 201A	1	Various modems used
AT&T	Schedule 4A Voice channel	2400	Bell 201B	1	Various modems used
AT&T	Schedule 4B Voice channel	3600	Rixon Sebit-36M	2	Capability based on Rixon modem
AT&T	Schedule 4C Voice channel	4800	Rixon Sebit-48M	2	Capability based on Rixon modem
AT&T	Broadband channel	19,200	Bell 303A10	12	
AT&T	Broadband channel	40,800	Bell 301B	12	
AT&T	Broadband channel	50,000	Bell 303A20	12	
AT&T	Broadband channel	230,400	Bell 303A30	60	
WESTERN UNION	Class A Teleprinter channel	50	W.U. 1181-A	1/12	
WESTERN UNION	Class B Teleprinter channel	57	W.U. 1181-A	1/12	
WESTERN UNION	Class C Teleprinter channel	75	W.U. 1181-A	1/12	
WESTERN UNION	Class D Teleprinter channel	180	W.U. 1181-A	1/8	
WESTERN UNION	2KC Broadband data channel	600	W.U. 1601-A	1/2	
WESTERN UNION	Class E Broadband data channel	1200	W.U. 2121-A	1	
WESTERN UNION	Class F Broadband data channel	2400	W.U. 2241-A	1	
WESTERN UNION	8 KC Broadband data channel	4800	—	2	
WESTERN UNION	16KC Broadband data channel	9600	—	4	
WESTERN UNION	48KC Broadband data channel	28,800	—	12	

SUMMARY OF CHARTS ON DATA COMMUNICATIONS TERMINALS AND SPECIAL PROCESSORS

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GRAPHIC DATA SYSTEMS and DEVICES

"Graphic Data Systems" is a term which refers to the technology whereby essentially pictorial information is entered into, processed by, and recovered from digital computers. Many different types of systems fall within this definition. There are systems for entry of graphic data such as document or film scanners. Systems for recovery include CRT displays and plotters. There are systems for close-coupled entry and display such as the ubiquitous "Cathode-Ray-Tube-Light-Pen" consoles. Associated with each of these device-oriented systems is a complex programming problem.

There is today a considerable interest in graphic data systems, or "computer graphics", to use an equivalent term. This current interest focuses to such a great extent on the concept of man-machine communication through CRT consoles that it almost masks the essential fact that the field of computer graphics is much broader; that in fact, important graphic problems are completely beyond the capability of these attractive and versatile consoles. It is, therefore, essential that any technical survey presents a complete and balanced view of the field.

An interesting characteristic of this current upsurge of interest in computer graphics is that it is motivated essentially by "non-hardware" considerations. One prime source of motivation is the computer industry's continued search for new applications and its current attack on the area of engineering design (computer-aided design). Another source of motivation is the desire to find better methods for communications between man and machine, independent of whether or not the problem is inherently graphic (interactive processing).

From a hardware viewpoint, graphic data systems consist essentially of four types of elements: input (graphic-to-digital), output (digital-to-graphic), processing, and storage. Graphic input and output technology is based upon three areas of device technology—the cathode ray tube, facsimile equipment, and the plotter. The basic characteristics and limitations of these devices are dominant factors in product development. The limitations are rather fundamental and have the effect of preventing graphic input-output technology from developing more than moderately in spite of the great increases in capability realized in computer technology and the great interest from both the private and government sectors in achieving major breakthroughs. This section covers processing and storage functions that are achieved using conventional digital computer systems and storage media. A more general treatment of processing and storage of graphic data would naturally include such areas as film, optical systems, analog video, etc.

Graphic data systems impose very substantial requirements upon software. The programming of a graphic system often has to embody the results of analysis of problems of an extremely difficult type. The greatest of these problems is that of pattern-recognition, for which acceptable solutions have been found only in the limited case of printed character recognition. Another problem of substan-

tial magnitude is that of the graphic language that enables the user of a console to communicate "graphically" rather than in conventional terms. Aside from the difficulties in creating a language which is powerful from the user's viewpoint, there is the very real problem of excessive computer memory and running time requirements that seems to be characteristic of graphic languages. Hardware is frequently employed in graphic input/output systems to perform certain processing functions that would be very time-consuming if done by stored-program control (pattern pre-processing, character generation, etc.), but this does not alter the critical characteristic of the "soft" parts of the graphic data processing problem, namely, the uncertainty that they can foreseeably be solved in an economically attractive way.

In this section, particular emphasis is given to equipment although the importance of "software" has hopefully been made clear. Products and technology covered in this survey are restricted to those that have a direct meaningful connection to a digital computer system. There are many other interesting graphic technologies that are not included in this section because their connection with digital computer technology is somewhat indirect.

BASIC CHARACTERISTICS Functions

A graphic data system, functionally speaking, is a system which permits the user to exchange essentially pictorial data with a computer and obtain processing results that embody graphic concepts. To give this definition more meaning, it is necessary to develop a workable, detailed definition of graphic data and to give similar detailed definitions to graphic processes. Graphic data originates as a visible image. From the viewpoint of computer operations, this data may be considered in three classes which depend on how readily the raw image may be defined or how compactly it may be represented in digital form. These classes are as follows.

- Symbolic—Symbolic data is visual data that is completely representable by a statement as to which of a finite set of symbols the data represents. The best example of this type is alphanumeric data which is completely representable by a character code and, if necessary, by a font type and a location.
- Functional—Functional data is visual data that is completely representable by a reasonably compact mathematical expression.
- Pictorial—Pictorial data is visual data that is representable only by a complete

description of the state of every resolvable point in the array on which the image is either scanned or composed. The description may be either "on-off" for a line image or may be a number indicating brightness on a discrete-step grey scale. Although there are a number of useful approaches to encoding this type of information to achieve compaction in storage, fundamentally, pictorial information is representable only by an indefinitely-long list of point descriptions. An important sub-class of pictorial data is the data which represents a single line or stick-figure image of a mechanical component. Such images can be compactly represented by groups of truncated straight lines, each line individually meeting the specifications for functional data, but no functional rule being possible for naming the set of lines. Thus, this sub-class of data is somewhat a hybrid of pictorial and functional data.

These definitions are most naturally associated with graphic data viewed as input to a system, and to a lesser extent as data to be stored and displayed. The significance of these distinctions is developed when the question of graphic processing functions is raised.

Graphic processing functions can be considered in three classes.

■ **ENTRY**—The entry of graphic data into a digital computer system from a visual source involves several possible processes:

1. Scanning, recognition, and definition as a discrete symbol;
2. Scanning, analysis, and definition as a set of parameters of a mathematical function;
3. Scanning, possibly compaction, and storage of a pictorial image array;
4. Scanning and association of data with previously stored data.

■ **DISPLAY**—Display in graphic form of previously received graphic data involves several processes:

1. Displaying image of discrete symbol based on defined symbol;
2. Displaying graph of defined function;
3. Displaying pictorial data;
4. Determination of symbolization required by analysis of data;
5. Transformation of data from storage format to display format.

■ **PROCESSING**—Some processing functions that are essentially graphic in their objectives are:

1. Changing the overall geometric basis for the image (scale, projection, viewing angle);
2. Selective displaying of sections of images;
3. Combination and overlaying of images;

4. Distortion and constraining of images;
5. Editing of graphic records;
6. Creation of graphic records by analysis of data.

Techniques

A discussion of techniques for graphic data system implementation is oriented around a discussion of graphic input/output devices and their key technological limitations. Graphic devices fall into three major groups.

- Input devices—Document scanners, graphic recorders, and film scanners.
- Output devices—Plotters, CRT displays, and film exposing printer plotters.
- Interacting devices—CRT consoles with input capability.

The extent to which these devices can be used in any given application is determined by certain basic technological limitations which are discussed below.

- Resolving Power—A fundamental limit on all graphic I/O devices is their ability to resolve an image into a set of individual points. This limit applies equally to input and output devices.
- Image Fidelity—Another important limit on graphic I/O devices is image fidelity including grey-scale rendition, linearity, color rendition, and accuracy of image positioning.
- Display Capacity—Certain display devices are definitely limited in the amount of image detail that can be shown at once.
- Computer Requirements—The computer requirements of a graphic I/O device are limitations that may be considered economic when they take the form of memory and running time requirements, or may be considered technological when they take the form of a functional requirement such as pattern recognition that may not be capable of being met under any reasonable condition.
- Operability—Graphic input devices frequently involve manual operations. There are distinct limits on the ability of a human being to achieve results superficially available with a given instrument due to its operability (or inoperability).

Graphic data systems employ several different system concepts. In certain cases the graphic I/O device may be operated off-line from the digital computer with magnetic tape serving as the interface medium. In other cases, the graphic device may be tied-in directly on-line to the computer. Systems employing the off-line approach frequently make use of special-purpose processors in the off-line configuration to achieve flexibility and minimize demands on large computational facilities. For economy, on-line CRT display systems almost

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invariably employ special processors between the displays and the main computer.

Applications

Graphic data systems are used in many applications for very specific input or output operations where the concept of an integrated graphic system is not a major factor. In most of these cases the requirement is for specific entry or display functions to be performed, such as document reading or curve plotting. The concept of a complete graphic data processing system with graphic input, processing, and output is relatively new. Most of the applications are found in the automation of engineering design. A basic characterization of these applications is given below.

ENTRY ONLY

1. Document reading (checks, bills, credit-card forms).
2. Graphic recording and film scanning (scientific data acquisition).

DISPLAY ONLY

1. Plotting (charts, graphs, templates, design studies).
2. Film plotting (charts, graphs, printed reports).
3. CRT display (printed reports, tracked object presentations, etc.).
4. Photo-typesetting.

INTERACTIVE SYSTEMS

1. Computer-aided design.
2. On-line programming and data system operation.
3. Instruction.
4. Remote inquiry and conversant systems.

PEN MOVING PLOTTERS

Pen moving plotters (or simply "plotters") are drafting machines capable of being driven under computer control. Functionally speaking, a plotter is a machine that can draw a line or a symbol on a sheet of paper or film. Plotters are available in a wide range of capabilities and prices. Plotters differ from other graphic output devices that are based on facsimile or cathode ray tube technology in the following particulars.

- Plotters are generally capable of drawing line images of very high resolution, unlimited density, and virtually unlimited size.
- Plotters are capable of producing output on virtually any medium capable of accepting markings.
- Plotters "draw images" rather than compose them on a raster.

All plotters have the same basic functional elements (although in certain cases some of those functions may be provided in a central computer rather than in the plotter itself). These basic functions are:

Storage for a series of plotting commands;
A pen (or set of pens) mounted on a

carriage that can move freely in two coordinates;

A paper-holding mechanism;

A control system for reading the plotting commands and translating them into the proper sequence of pen motions.

The performance of plotters is generally reckoned in terms of the accuracy and precision with which they can execute pen motions in response to commands. Speed, paper handling capability, and the sophistication of the internal control system are also important characteristics. As plotters which are currently-available exhibit a wide range of performance, it is necessary to discuss this subject in some detail.

The most fundamental performance feature of a plotter is its accuracy. The accuracy of a plotter is a measure of its ability to plot points or lines "where they should be" anywhere on the plottable surface. Since high accuracy is achievable only through expensive construction, plotters generally are manufactured in two distinctive product groups—utility plotters and precision plotters.

Utility plotters normally have an accuracy of less than 0.01" (meaning these plotters make positional errors of 0.01" or more). Actually, the accuracy of these plotters is somewhat sensitive to the size of the plottable surface and more properly expressed as a fraction of full scale, on the order of 1/1000 to 1/4000, rather than an absolute distance. Utility plotters are quite accurate enough for producing curves of scientific or business data, for schematic drawings or templates for cutting products whose accuracy requirements are relatively low, such as fabric or sheet metal and other low-accuracy tasks. Utility plotter mechanisms are light and inexpensive. The linework produced is not of the highest quality.

Precision plotters are available with accuracies in the range of 0.005" to 0.001". These plotters are used for work where high accuracy is essential. Applications include printed-circuit and integrated-circuit artwork, map graticules, and high-precision templates. Plotters built to meet these accuracy requirements frequently are also required to prepare very large graphics and the accuracy specifications must be held everywhere on a large working surface (typically 40" x 60"). Since meeting these requirements for accuracy and size alone make the plotter quite expensive, it is normal to find these machines equipped with a variety of special control features intended to maximize the usefulness of a very substantial investment.

Closely associated with accuracy as a plotter specification is repeatability, which is the ability of the plotter to return to the same point on the plotting surface in response to a repetition of a coordinate positioning command, even if the point in question is not where it should be. Repeatability is governed by fewer factors than those that affect accuracy and therefore is generally better than accuracy on any given plotter.

The precision of a plotter, its ability to resolve fine detail, is another measure of its performance. Precision is more closely related to repeatability than to accuracy, and will generally be at least as good, numerically, as repeatability.

The productivity of a plotter is a direct function of its achievable plotting speed. Plotting speeds

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range from roughly 1 inch/second to 20 inches/second. The higher plotting speeds are generally available only in the less expensive utility plotters or in the precision plotters at some sacrifice in accuracy. Speeds are sometimes necessarily limited by the requirements of the pen or recording tool (a scribing point or light source). Many plotters are capable of running at a variety of speeds. A common feature is a high-speed slewing mode (with the pen up) of roughly ten times normal plotting speed. Plotters driven by an analog servo are capable of travelling at a relatively-high speed in a continuous or free-running mode.

Plotters are built in two basic physical forms: flat-bed and drum. The flat-bed style is versatile and used in inexpensive utility plotters as well as in precision plotters where it is mandatory. It will accept any type of paper or other media that will fit on the table. The drum plotter is simple and very compact. The pen is driven only in the Y-axis as the paper feed drum can be driven in both directions to supply X-axis motion. The limitations of the drum plotters are its inherent low accuracy in the X-direction and the requirement that special paper be used for all plotting tasks.

The pen motion system for the plotter may employ either an analog servo or a digital stepping motor drive. An analog servo drive requires that a position-sensing potentiometer or encoder be coupled to the pen carriage to supply a feed-back signal. A digital stepping motor drive theoretically does not require position-sensing since a running count of stepping pulses delivered to the motor is intended to indicate the pen carriage position. For low-accuracy utility plotters this assumption is valid and gives the digital drive an economic advantage over the analog drive, particularly when the plotter is coupled directly to the output channel of a digital computer. For high-accuracy plotters, position-sensing is required regardless of the type of drive.

The type of driving motor used affects other aspects of the plotter's performance. A digital motor drives the plotter in discrete steps. If the steps are large, allowing high speed, then the "stair-case" image inherent in the digital drive will be noticeable and perhaps unacceptable. If the step size is small, on the order of 0.001", as is the case in some high precision plotters, then the "stair-case" image is imperceptible to the naked eye. Analog drives are capable of accepting direct motion commands from one point to another and producing perfectly smooth lines. It is always possible to plot a complex curve by decomposing it into a succession of straight line segments each of which is plotted separately. With analog servo drives, it is possible to obtain rather high plotting speeds for complex curves by issuing direction commands to the plotter in time with its motion, thereby avoiding start-stop plotting of every line segment.

Plotters are available with a wide range of control concepts. The simplest approach to plotter control involves direct coupling of a digital step-motor driven plotter to a data channel of a computer. With this approach, all computation of plotter commands is done by programs executed in the computer and the plotter receives nothing but a sequence of pulses which drive the stepping motors back and forth, plus the necessary pen-up and pen-

down commands. This approach is economical when viewing the costs of adding a plotter to an on-going data processing system where plotter use is intended to be relatively light. The highly economical "skeleton" plotter control just described relies upon program control to convert vector and symbol commands such as:

"Plot line from (X₁, Y₁) to (X₂, Y₂)"
"Print A B C D starting at (X₃, Y₃)"

into a sequence of step-motor pulses and pen up/down commands. A number of plotters are equipped with self-contained control systems that allow the plotter to interpret these commands directly. Such plotters are intended for operation without direct connection to a computer and are equipped with either card, paper tape, or magnetic tape input. Analog servo driven plotters normally operate from absolute coordinate information of the sort given in the example above and easily accept manual control of scale, offset, and pen position. Step-motor driven plotters require a considerable amount of logic to provide comparable local control.

The most comprehensive plotter controls are intended to make the entire system highly versatile and capable of performing many functions without requiring use of a large-scale computer. These controls are naturally used with the large high accuracy plotting tables. Features available in these systems include:

- Direct printing of symbols (from turret);
- Selection of pen type (turret-mounted);
- Selection of line type (solid, dashed, etc.);
- Searching of input tape for specific records;
- Generation of strobed symbols (pen-stroked);
- Scaling, offset, and rotation of axes;
- Linear interpolation;
- Curvilinear interpolation;
- Curve following (with creation of digital record).

The most comprehensive of these control systems actually employs a self-contained digital computer.

Plotters record information on a variety of media. Utility plotters are generally confined to inked-pen tracing on paper. Drum plotters require the use of special paper to fit the feed mechanism. Flat-bed plotters will accept any medium that will fit the table. The more expensive precision plotters can handle a variety of media. Inked-pen on paper is commonly used but highest quality work is produced by scribing of lines in an opaque surface on a dimensionally-stable plastic, or exposing a photographic negative on a similar backing. It is thus normal for precision plotters to be equipped with pen turrets and replaceable carriages to permit recording on a variety of media.

FILM PLOTTERS

Film plotters are systems for exposing photographic film from a cathode ray tube image. They are capable of producing images of moderate quality on film at a very high rate of speed when compared to pen moving plotters. The quality of the images produced by these machines is essentially limited by the inherent properties of the cathode ray tube. The output of these plotters is a rather small film image and subsequent use generally requires projection and possible printing of an enlargement.

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Film plotters usually have the following basic elements:

- A magnetic tape transport to hold image driving tapes prepared on a computer.
- A cathode ray tube which generates symbolic vector images in response to commands originating on tape and interpreted by the plotter's control section.
- A film transport system including feed reel, exposure gate, in-line developing system, and take-up reel.
- A slide projector for superimposing standard form information on the film being exposed.
- A monitor system to permit in-line examination of film immediately upon development.
- An internal control system.

The key limitation on performance of film plotters are those imposed by the cathode ray tube used to generate the images. Since the face of the tube is used to compose the entire image exposed on a single film frame, the CRT's characteristics place an absolute limit on the accuracy and resolution of the resultant image. Allowing for differences in the form of various manufacturers specifications, it is generally found that on the average, film plotters offer resolution of image to a grid of 2048 X 2048 points (one part in 2000) and positional accuracy of roughly 1 percent.

The limitations described above are based upon the principle that the film image is composed from a single CRT image. It is quite possible to avoid this limitation by designing a film plotter in which the film image is composed from several CRT images. To make such a system operate it is necessary to provide a highly precise mechanical film transport that can index the film relative to the CRT. Such systems are available now or in development, but are not in extensive use. Geo-Space Corp.'s Digital Film Plotter and Information International's PFR-3 Film Scanner listed in the product summary charts that follow this discussion have this type of mechanism.

Film plotters offer a variety of features. The images may be composed using various combinations of character and vector generation. Films of various sizes may be exposed, including 16mm, 35mm, and 105mm microfiche. Monitoring is available using either direct projection viewing, or printed full size hard copy. For information storage and retrieval applications, these plotters can expose a retrieval bar code on the edge of the film. The simpler models are restricted to character printing in a fixed format. The more elaborate models allow free composition of alphabetic and graphic data. Slide projectors may be used to superimpose standard forms on the film being exposed. The positioning of the projected image relative to the CRT image is accurate to roughly 1/2 percent.

The speed of film plotters is limited primarily by the density of the images being plotted and the writing speed of the CRT. Practical speeds on the order of a frame a second are achievable.

GRAPHIC RECORDERS

Graphic recorders are devices used to extract information from previously-recorded images and convert it directly into digital form. These devices

are designed to be used on a wide variety of source data with no specific standards imposed as to format, image quality, or information content. There are three basic types of devices in this class—manual curve followers, automatic curve followers, and film scanners.

Manual Curve Followers

A manual curve follower consists essentially of a freely-movable arm coupled to X-axis and Y-axis position indicators, a control unit, and a recording mechanism. The arm is positioned over a flat work surface on which the graphic source is mounted. In operation, the arm is moved over the graphic source and positioned over image elements of interest. Positional information as well as textual information is recorded when appropriate, the decision in either case being made by the operator.

The performance of manual curve followers is determined by the pointing accuracy and resolution of the device, and the recording speed achievable by the operator. Most manual curve followers on the market are intended for use in applications where moderate accuracy and good recording speed are desired. These devices generally yield accuracy in the range of 0.004" to 0.015" on work surfaces of 18" X 24" up to 40" X 60", and recording speeds of 500 to 1500 points per hour under realistic operating conditions. Resolution of these devices varies from 0.001" to 0.015" and is quite independent of accuracy. It is questionable whether the very high resolution claimed in certain of these devices is useful in view of the limitations that generally prevail on the operator's visual acuity, the quality and stability of source graphics, etc.

Serial keyboards or thumbwheel panels are furnished on most graphic recorders for entry of textual information. The ease with which the operator can perform this operation is another performance-limiting design factor.

It should be mentioned, in passing, that there are manually-operable graphic recorders available capable of yielding accuracy better than 0.001". These devices are precision coordinateographs, normally operated by feed screws, and are designated for use with a low-power microscope. As their recording speed is extremely low, on the order of 10 points per hour, these devices are considered more in the nature of precision instruments for industrial measurement rather than graphic recorders of reasonably large quantities of data for computer use.

Manual curve followers are available in a number of basic product configurations. The most common configuration resembles a drafting machine and consists of a two-axis traveling carriage mounted on a conventional drafting board. Position sensing is accomplished using either optical coding or potentiometers coupled to the carriage. This type of curve follower is useful in taking recordings from very large source graphics, particularly when data points are rather widely spread. The mechanism is rather bulky and its inertia is high. These factors limit the usefulness of this type of follower in situations where the data is intricate and small but frequent differences must be recorded.

There are a number of manual curve followers available that provide very high agility for recor-

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ding intricate curves. Their basic drawback relative to the large drafting machine type discussed above is that the size of the work surface is somewhat limited. The mechanizations of these high agility followers are rather individual and ingenious.

They are briefly discussed below.

MAGNETICALLY-COUPLED PLOTTER— The Edwin Industries' "Pencil Follower" features a very lightweight cursor which generates a magnetic field. Under the work surface, which is glass, there is a two-axis carriage similar to the carriage found in flat-bed plotters. On the carriage is a magnetic pick-up which senses the signal emitted by the cursor. The carriage is servo-driven to follow the cursor, and pulley-driven shaft encoders give the positional information.

OPTICAL GRID SENSING FOLLOWER— The Concord Controls' "Floating Arm Graphic Recorder" features a light well-balanced arm which is positioned by the operator over the graphic. Underneath the table is a branch of the arm containing a light source which traverses over a glass plate on which is etched a grid pattern. As the light source moves about, a photocell underneath the glass plate picks up the beam. Interruptions of the beam caused by the grid pattern are detected as pulses. These pulses are fed to counters that indicate cursor position.

CAPACITY DRIVEN PENCIL— The Bolt, Beranek, and Newman "Grafacon", also known as the "Rand Tablet", uses a free-moving pencil that receives position-indicating pulse signals by means of capacitive coupling. The signals are generated in the writing surface. A unique design of the writing surface permits each point on a 1024 x 1024 element field to be uniquely identified by a 20-bit pulse code which is picked up by the pencil.

PULLEY-DRIVEN ENCODER— Calma and Auto-trol make a product that utilizes shaft encoders coupled to the cursor by a string and pulley system. Calma uses a magnetic encoder while Auto-trol uses an optical device. (See product summary charts for more information on these models.)

The manual curve followers previously described are generally usable for any type of graphic source material that can fit on the work surface. Many of these units can be equipped with media transport accessories such as spoolers for strip charts and film projection systems. Certain curve followers are made specifically for conversion of strip charts.

All of the devices in this class are basically capable of recording data on any conventional medium such as card, paper tape, or magnetic (usually incremental) tape, although not all products are offered with these options. The device used to make the final record can possibly limit the recording speed of the curve follower, depending on the rate at which data is being generated and the formats used. This is a significant design consideration that should not be overlooked in choosing a system.

Automatic Curve Followers

The fact that manual curve following is tedious and error-prone has created an interest in the automation of the process. The simplest product concept for automatic line following involves the use of a plotter equipped with a photosensitive head in place of pen to follow the line automatically. The photohead detects the line by virtue of its relative brightness and signals a control system which drives the plotter in a specific pattern. The plotter pattern permits the photocell to determine the edges of the line and to seek a direction that steers the plotter along the line. The performance of these followers is critically dependent upon the clarity of the line being followed and the absence of any extraneous lines that might mislead the follower.

Film Scanners

Film scanners represent another approach to the automatic acquisition of graphic data in digital form. The working end of a film scanner is essentially a CRT flying spot scanner. The flying spot scans a frame of previously exposed film and the scanned pattern is digitized and transmitted to a general purpose computer for subsequent analysis. The raster over which the spot moves is considered as a grid on which the film image can be analyzed.

Film scanners in use are best described in terms of the accuracy and resolving power of the scanner section. For single frame systems (one CRT image to the film frame), the limits are consistent with CRT performance as discussed elsewhere. Systems are available in which the CRT pattern interrogates a small portion of the film frame at a time and a high precision film transport is programmed to obtain full coverage of the film. Such an approach is capable of extending the accuracy and precision of the scanner to considerable lengths, depending on the quality of the film transport.

The type of mechanism described above is quite capable of reading a graphic and creating a digital record of the image. Such a record, however, is raw and unprocessed data. In most applications it is necessary to be able to identify the information in the source, to distinguish various sections of this information, and to make estimates of true values of the information on the basis of redundant or possibly erroneous information in the raw data. Such processing functions require considerable and analytic and programming effort and can, furthermore, require substantial amounts of computer time. In many interesting cases the feasibility of accomplishing such data reduction automatically has yet to be demonstrated. The usefulness of film scanners in automatic graphic data reduction is accordingly limited not so much by the instrumentation as by the consequent requirement for automatic data reduction.

CATHODE RAY TUBE CONSOLES

Cathode ray tube consoles are used extensively to display graphic and alphanumeric data originating in a computer. Most consoles are equipped with a means for the viewer to enter information into the computer. Entry devices include keyboards, devices for pointing at items appearing in the CRT

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display, and devices for creating items in the display. These consoles have both input and output capability but they are most appropriately considered devices through which the viewer "converses" with the computer. The ease with which these consoles allow man-computer conversations has caused them to be employed in situations requiring strictly alphanumeric information exchange as well as in cases where the data has a genuine graphic characteristic requiring visual display.

From the users' viewpoint, the performance of CRT consoles is largely determined by the image quality produced by the cathode ray tube. Other performance limitations are imposed because of the computer time required to execute functions desired by the operator and by the availability of software to execute the users' commands. The limitations and operational requirements of cathode ray tubes and the normal requirements of these displays for computer time are primary factors influencing the implementation of these consoles. Allowing for variations between manufacturers' products, cathode ray tubes available today are capable of resolving an image into a grid of roughly 1,000,000 to 4,000,000 discrete positions with a positional accuracy of perhaps 1% of full-screen dimensions. These two restrictions place an upper limit on the quality of the image.

In most consoles, the tube has no image storage capability and it is necessary for the image to be regenerated on the order of 40 times per second to achieve a flicker-free appearance. This requirement places an upper limit on the richness of the image because it implies an upper limit on the number of places to which the beam can be directed.

There are three basic methods for controlling the CRT beam: raster, vector, and shaping. Raster-type control involves scanning the beam over a fixed pattern, usually rectangular, and obtaining an image by intensity modulation. Vector control involves steering the beam directly between two points in the display grid. Shaping involves passing the beam through an aperture in a mask, the aperture imparting the shape of a desired symbol to the beam. Raster control is the least expensive method and gives the lowest quality image. Vector control gives high quality images and good character definition. Beam shaping is employed exclusively for character generation. It gives highest quality character display but is somewhat inflexible, as only characters designed into the generator (a beam-shaping tube) can be displayed.

Cathode ray tubes utilize electrostatic or electromagnetic beam deflection. The electrostatic approach yields very high deflection speeds but has disadvantages when compared to the electromagnetic approach. Electrostatic devices require operating voltages too high for semiconductor devices if the beam is to be steered over a large area. Electromagnetic deflection systems require relatively low driving voltages (well within the capabilities of semiconductor devices), produce a smaller and brighter beam than possible with electrostatic deflection, but yield relatively-low deflection speeds.

To display graphic data and position characters, it is necessary that the beam be moved over the entire face of the tube. The desire for a bright sharp image dictates that electromagnetic deflection be used. Generation of characters through beam motion requires only small amplitude changes but

very high deflection speed if many symbols are to be shown. To meet both these requirements and permit rich images to be displayed, cathode ray tubes are equipped with dual deflection systems—conventional electromagnetic deflection for images and character positioning and electrostatic or special high speed electromagnetic deflection for generating the character delineating pattern.

Character shapes can be created by program control of the beam's position but this approach generally requires too much computer time. Several approaches exist for generating character shapes directly in response to a simple character-indicating code. Characters may be generated by beam shaping as previously mentioned. This approach involves use of a CRT with a special element in it—a mask with apertures through which the beam is extruded. High quality character images are produced this way but the available alphabet is frozen into the mask inside the tube and cannot be changed except by replacing the tube. Electronic methods of character generation by beam steering are preferred in displays because they are flexible and economical at some sacrifice in image quality. An electronic character generator may be shared by several display consoles.

There are two basic electronic approaches to character generation: raster and function. The raster approach involves generation of the character as a set of lines or dots selected from a fixed array. (The typical array for a dot pattern is 5 columns by 7 rows). Characters generated in this manner tend to show the raster or array pattern very clearly. The functional approach to character generation involves steering the beam through a sequence of strokes or dots that creates the character shape. There need not be a fixed array upon which the character is shaped but the functional approach generally relies upon composing the character out of a set of basic image elements.

To maintain a flicker-free image on the face of the CRT requires regeneration at a rate of roughly 40 frames per second. A reasonably rich display may have several thousand picture elements: characters or vectors. Each element requires an independent display driving command. Such a load, on the order of 30,000 to 90,000 commands per second, would monopolize the time of a computer furnishing the display with control information. It is normal practice to remove this load from the computer by providing the display with a local storage device and a simple image regeneration control. Storage is furnished in a variety of ways: core memory, drums, delay lines, and scan converter tubes.

For applications where more than one display is to be used it is common to centralize the display buffer memory and character generator in a central control that can be time-shared by several consoles. Different approaches are offered to suit individual requirements. If the consoles sharing the central control are to be used for independent operations, the buffer is generally a core memory, and vector generation of images is used. If the displays are all to see the same information, a TV raster system is the least expensive and the storage function may be implemented using scan converter tubes as well as digital methods.

Cathode ray tube consoles normally provide the viewer with a mechanism for entering information

EQUIPMENT CHARACTERISTICS REVIEW

either calling for a display or in response to the contents of one. In simple applications where the display is used to present alphanumeric information in page format, a keyboard is usually sufficient as an entry device. In any case where it is necessary for the viewer to point at specific information in the display, a pointing device is required.

Pointing at an element of a display or creating information by "drawing" is accomplished using one of three approaches: light-pen, cursor, or associated graphic recorder. The light-pen is a wand containing a photocell that is held over the face of the CRT by the viewer. When the beam passes within view of the wand, a signal is picked up by the photocell and returned to the computer. Since the time delay is very small, the computer knows where the beam is when the signal is picked up and uses this information to identify the point in question. When the light-pen is used to identify an existing element of a display it senses the beam that is producing the image in question. The pen can also be used to introduce new information into the system. In this mode, a small beam pattern is generated and acquired by the pen. As the pen moves, the pattern follows it, the exact position of the pen within the beam pattern being computed from the pen's response to the pattern. A spot of light, serving as a cursor, can be positioned by keyboard control or a "joystick." This approach is convenient when the display is limited to a fixed array such as a written page. It is possible to couple a graphic recorder to the same computer that is driving the display. Information entered from the graphic recorder can be presented on the CRT instantly. This approach is desirable when graphic information originating on a document is to be entered into the computer. The graphic recorder's performance is not limited by the CRT and the documents will not block the operator's view of the tube.

DOCUMENT READERS

Document readers are systems for reading printed or marked information on paper or card forms and translating this information into computer input form. These systems will read graphic information if it meets format, legibility, and locational tolerances and either record the information on a conventional medium such as punched card or feed it directly into the memory of a computer.

Document readers are normally designed to handle specific types of documents that have been marked or imprinted with specific type fonts. Flexibility is provided in some products but at a premium price. Some examples of the types of documents for which these systems are designed are given below:

- Sales register tapes
- Punch cards with typewritten or marked information
- Mark sense sheets
- Typewritten pages
- Checks (magnetic-ink printed account number)

As can be seen, typewritten pages represent the only document type with a free format. The other document types all have simple, easily specified formats.

Document readers can interpret information that

meets certain typographic requirements. There are three basic typographic forms to consider:

1. Type Fonts

Typed and printed information can be read if the font used is one for which the reader is specifically designed. There are about 15 different fonts in use, for both optical and magnetic sensing.

2. Mark Sensing

Pencil marks that are properly positioned on a mark sense form can be read by optical means. This technique has a great advantage over printing where the originator of the form has no access to a typing or printing device with the proper format (field survey, retail sales etc.).

3. Hand Printing

Hand printed numerals can be read optically if the printing meets certain format requirements. This approach has the same advantages over type fonts as does mark sensing with the added advantage of compactness.

The performance of document readers is normally measured in terms of productivity, documents read per minute, and flexibility in reading fonts and correctly interpreting imperfect printing. The speed of a document reader may be easily expressed in characters per second but is better expressed in achievable documents per minute. This latter rating takes into account both paper handling ability and the reader's ability to avoid scanning blank areas in the document. Flexibility in being able to read several fonts and to handle various size and format documents is a valuable performance feature in cases where such versatility is required. In cases where design of forms is completely within the control of the data processing organization and where large quantities of identical forms are being processed (utility and gasoline billing, for example), flexibility is of little value. The ability to cope with imperfections in the printed matter while still making correct interpretations is an important performance feature since it directly influences document reading rates.

Document readers are composed of the following basic elements:

1. A document transport that picks up documents from a feed hopper, passes them through the reading systems, and deposits them in output stackers;
2. A reading system that contains a device for scanning the face of the document and sensing the presence of images;
3. A recognition system that analyzes the information picked up by the scanner and indicates which character, if any, has been read;
4. A recording unit or a computer interface unit to which is sent a data stream of recognized characters;
5. A control section.

The document transport system utilizes moving belts, friction, and vacuum techniques to pick up documents and move them through the processing

EQUIPMENT CHARACTERISTICS REVIEW

stations. Some transports move the document through the reading stations without stopping, while others bring it to a halt at that point. The latter approach is more flexible because it allows the scanning system to inspect the document for as long as necessary, in order to recognize characters that may not have been successfully recognized on a previous pass, to adjust for skewed or tilted lines, and to be programmed freely to inspect documents of any format.

Scanning may be accomplished using one of a number of techniques. Nipkow wheels are employed in simple systems. Flying spot scanner, vidicons, and arrays of photocells are used in systems designed for high character reading rates and flexibility in document formats and fonts. Recognition is accomplished by either optical matching or one of a number of electronic approaches. The approaches used differ in their tolerance, range of symbols they can detect, and the ease with which they can be adjusted to allow changes in font.

The control section of the reader may be self-contained or it may depend upon execution of stored-program functions in the computer to which the reader may be connected. Self-contained control units perform fixed functions with operator control and selection of options being possible through a

control panel or a plug-board. The ultimate in self-contained control is obtained by use of a small general purpose computer in the reader.

Typically, the control functions performed within the reader (or provided by the connected computer) include:

- Document advance
- Variable format document scanning
- Scan adjustments and repetitions
- Operator insertion of substitute characters for "unreadables"
- Checking
- Accumulation of totals
- Adjustment of output data format
- Data transmission to computer
- Interpretation of edit commands printed on the document
- Insertion of fixed data into output data stream
- Document delivery into output stackers or punch
- Record sequence numbering

Design features naturally vary between readers, but most of the functions listed above are considered common.

GRAPHIC RECORDERS (AUTOMATIC CURVE FOLLOWERS)

MANUFACTURER	MODEL	OUTPUT	RESOLUTION (step size)	INPUT KEYBOARD	PAPER SIZE	SPEED	PAPER ROLL FEED	COMMENTS
Calcomp	471	200 bpi magnetic tape	0.01" or 0.005"	7 keys	30" x 120 ft. (drum) 35" x 38" (flatbed)	150 points/sec. (1 count per point)	Available for flat-bed as well as drum model	Searches for and automatically traces continuous lines of 0.030" or 0.015" minimum widths

GRAPHIC RECORDERS (FILM SCANNERS)

MANUFACTURER	INFORMATION INTERNATIONAL	INFORMATION INTERNATIONAL	INFORMATION INTERNATIONAL	GENERAL PRECISION	IBM
MODEL	PFR-1	PFR-2	PFR-3	LINK	2281
FILM SIZE	16 mm. 35 mm. 70 mm.	Cut film 35 mm. to 5"x5"	16 mm. 35 mm. 70 mm.	16 mm. 35 mm. 70 mm.	35 mm. up to 400 ft.
FILM ADVANCE	0.075" in 0.005 sec. (16 mm.) 0.047" in 0.005 sec.	0.05" in 0.005 sec.	0.075" in 0.005 sec. (16 mm.) 0.094" in 0.005 sec. (35 mm.) 0.047" in 0.005 sec. (70 mm.)		0.012" 0.756 in 0.147 msec.
PROGRAMMABLE SCANNING AREA	9-3/8" x 9-3/8"	3" x 3"	3" x 3"		3" x 3"
GRID SIZE	1024 x 1024	16,384 x 16,384	16,384 x 16,384	1024 x 1024 16,380 x 16,380	4096 x 4096
SCANNING AREA	10.5 mm ² (16mm.) 25.4 mm ² (35mm.) 60.3 mm ² (70mm.)	0.2" x 0.2"	10.5 mm ² (16mm.) 25.4 mm ² (35mm.) 60.3 mm ² (70mm.)		
SPOT SIZE	0.03" (9-3/8" x 9-3/8") 0.00132" (16 mm.) 0.003244" (35 mm.) 0.007816" (70 mm.)	0.001" (3" x 3") 0.0001" (0.2" x 0.2")	0.001" (3" x 3") 0.00144" (16mm.) 0.00336" (35mm.) 0.00784" (70mm.)		
ACCURACY		0.0002" on film			
MEMORY SIZE	8K-32K	8K-32K	8K-32K		
CRT DISPLAY MONITOR	16"	16"	16"	Yes	Yes
OUTPUT	Magnetic tape IBM 200/556 bpi	Magnetic tape IBM 200/556 bpi	Magnetic tape IBM 200/556 bpi	On-line to IBM 7040	On-line to IBM 360
TRANSFER RATE	9,000 char/sec	9,000 char/sec	9,000 char/sec		
MANUAL INPUT	Light pen	Light pen	Light pen	Light pen and keyboard	

FILM PLOTTERS

MFGR.	BENSON-LEHNER	CALCOMP	CONTROL DATA	GEO SPACE	IBM	STROMBERG-CARLSON	STROMBERG-CARLSON	STROMBERG-CARLSON	STROMBERG-CARLSON
MODEL	BL-120	835	283/284	DP-203	2280/2	4060	4460	4440	4360
DESCRIPTION	Film plotter	Incremental film plotter	Film recorder	Film plotter	Film recorder	Plotter-printer	Data recorder	Data recorder	Data recorder
INPUT	Magnetic tape	556/800 bpi	200/556 bpi	Yes	No	No	Yes	556/800 bpi 7 or 9 track	Yes
Computer	No	Yes	Yes	Yes	IBM System/360 Data Channel	Yes	Yes	Yes	Yes
SYMBOLS	Size	2 sizes	Symbols are drawn		3 sizes	4 sizes			
Orientation Control	Yes		Yes		No	Yes	No		
Number	64 characters		123 characters		63 characters	96 characters		63 characters	63 characters
HARD COPY OUTPUT AND MONITOR	Yes	Yes		Yes to 40" x 60"	Yes 60 sec. delay	Yes 60 sec. delay	Yes	Optional	Viewer
SPEED	16,380 char/sec	33,000 steps/sec.	110,000 char/sec	333,000 pts/sec	40,000 char/sec	40,000 char/sec	Up to 90,000 char/sec	Up to 90,000 char/sec	Up to 30,000 char/sec
MINIMUM LINE SIZE	0.01" at 15X		0.005"		2 resolution units or 0.00075" on film	2 resolution units	2 resolution units		
FORMAT	128 char/line 64 lines/page	Programmable	Programmable	204 char./line 150 lines/page	Programmable	Page	Page	Page	Page
RESOLUTION GRID SIZE	1024x1024	1100x1700		200 pts/inch linear	4096x4096	4096x3072	4096x3072		
ACCURACY	0.75% full scale		1% full scale						
DRIFT	+ 0.02% in 10 sec.	0.5% in 8 hours							
CHARACTER REGISTRATION	5% of char. height	N/A							
FILM	35mm. to 400 ft.	35mm.	35mm. or 16mm.	35mm.	35mm.	16 or 35mm. to 600 ft.	16 or 35mm. to 600 ft.	16mm.	16mm. or 105mm. microfiche
CHARACTER GENERATION	Drawn			Stroke generator	Shaped beam tube Stroke generator	Charactron tube	Charactron tube	Charactron tube	Charactron tube
FILM PROCESSING	Yes	30 ft./min. off-line		40 inches/min.	34 inches/min.				
RECORDING MODE	Character Vector Point plotting	Vector Point plotting	Character Vector Point plotting	Point plotting	Character Vector Point plotting	Character Vector Point plotting	Character Vector Point plotting	Character Vector Point plotting	Character Vector Point plotting
OPTIONAL FEATURES	64 additional characters; 9 track tape; 16mm. film			Exposes full size negative at 2000 square inches per minute by moving CRT with respect to film		Hand copy output Various cameras	Various cameras	Cameras; Hard copy; Multiple forms	Microfiche camera

PEN-MOVING PLOTTERS

MANUFACTURER	AIRBORNE INSTRUMENTS	ARISTO UNITECH CORP.	ARVIN SYSTEMS	AUTO-TROL	BENSON-LEHNER	BENSON-LEHNER	BENSON-LEHNER	BENSON-LEHNER	CALCOMP
MODEL	ORTHOMAT	8440/8450	1187/1197	6000 Series	Draftomatic	Delta Systems	DDS	LTE/STE	500 Series
DESCRIPTION	—	—	X-Y Plotter	Plotter and drafting machine	Magnetic tape drum plotter	Magnetic tape drum plotter	Stored-program drafting plotter	Plotters	Drum plotter
TABLE									
Plotting area	48"x48" 72"x140" Horizontal	31"x39" 79"x102" Horizontal (fixed)	11"x17" (1187) 30"x30" (1197)	50"x72" Horizontal (fixed)	11" width (Model 2) 29½" width (Model 1)	11" width 30" width	60"x60" to 60"x144" Tilttable	42"x58" Horizontal (fixed)	12" width 30" width
AXES									
Number	2 of 3	2	2	2	2	2	2	2	2
X&Y reversal	Yes	No	—	X&Y Inversion	—	—	Yes	—	—
Axis offset	Yes	No	Yes	Yes	—	—	—	Yes	—
SMALLEST PLOTTING UNIT	0.001"	—	—	0.001"	0.005"	0.005" 0.010"	—	—	0.005" 0.010"
ADJUSTABLE SCALING FACTORS	1/1000 to 1000X	—	—	5X to 200X	—	—	Up to 9999X	Yes	—
ACCURACY	±0.010"	±0.05mm	±0.001"	±0.004" (line) ±0.001" (Model 6300)	0.005"	0.005" 0.010"	0.002" (point)	—	—
REPEATABILITY	±0.003"	—	±0.0005"	—	—	—	0.001"	—	—
VACUUM HOLD	Yes	No	Yes	Yes	—	—	—	—	—
INPUT MECHANISMS									
Keyboard	Yes	—	—	Yes	—	—	—	—	—
Punched tape	Yes	—	—	5, 6, 7, or 8 level	—	—	8 level	Yes (STE)	—
Punched card	Yes	—	—	IBM 024/026	—	NCR or IBM	—	Yes (STE)	—
Magnetic tape	Yes	—	—	IBM 200 bpi	IBM 200/556 bpi	556/800 bpi	800 bpi 7 or 9 channel	200/556/800 bpi	200/556/800 bpi
Other	—	—	—	IBM 1620 computer	On-line computer	—	—	On-line computer (STE)	On-line computer
MAX. PLOTTING SPEED	400 inches/sec.	—	1500 inches/min. (slew)	150 inches/min. (15,000-0.01" line segments)	90 inches/min. (18,000-0.005" line segments)	90 inches/min. (18,000-0.005" line segments)	720 inches/min.	—	60/90/180 inches/min.
SYMBOL PRINTER	—	—	12 symbols	Rotatable 360° 384 symbols	—	—	—	—	Yes
SYMBOL GENERATOR	Yes	—	—	—	Yes	—	2.5 char./sec. 64/255 symbols	48 characters	—
CHARACTER SIZE	—	—	—	5/64", 1/8", 3/16", 1/4"	—	—	0.064"/1.024"	—	—
DASHED-LINE GENERATOR	Yes	—	—	Yes	—	—	—	—	—
CIRCULAR	Yes	—	—	Yes	—	—	Yes	—	—
INTERPOLATION OUTPUT									
Paper	Yes	—	Yes	Yes	—	—	Yes	—	—
Scribe cote	Yes	—	—	Yes	—	—	Yes	—	—
Film	Yes	—	—	—	—	—	Yes	—	—
Paper roll feed	Yes	—	—	Yes (automatic)	120 ft. length	100-120 ft. length	Yes (automatic)	120 ft. length	120 ft. length
PEN TYPES	Pens; Ball point; Scribes	—	—	Pens; Ball point; Pencils; Scribes	—	—	—	4 colors and line widths	Pens Ball point
MODES	Absolute Incremental	—	—	Absolute Incremental	Incremental (½" max.)	Incremental (½" or 1" max.)	Absolute Incremental	—	Incremental (½" or 1" max.)
SPECIAL FEATURES	Optional Parabolic interpolation; BCD, binary, ASCII codes	—	—	Reversed paper tape reading; Automatic file search on magnetic tape; Patch panel	Magnetic tape speed is 3 and 30 inches sec. (fast search)	Also accepts 9 channel 800 bpi tape; Uses a blocked format on tape	Routing head; Charac- ters can be rotated to 8 diff. angular orienta- tion; Digitizing head with CRT monitors	Magnetic tape speed is 3 or 30 inches/sec. (fast search)	—
COMMENTS	Teletype's Model 33 can be used as input. Core memory is 4K which can be increased to 32K.	Model 6300 has a drill, a high-speed milling cutter, and optical line follower options.	100/300 Series' models are without magnetic tape for on- line computer use.	Computer section includes a 4K core memory. I/O device is an ASR 33 Teletype.	Data on magnetic tape may be in gap or gapless blocked format.				

PEN-MOVING PLOTTERS (Continued)

MANUFACTURER	CALCOMP	CALCOMP	DISCON	ELECTRONIC ASSOCIATES	GERBER	GERBER	MILGO	MILGO	SYSTEMS ENGRG. LABS
MODEL	502	700 Series	2073	3000	600/800 Series	1000/2000 Series	4021D	4020A/D	80-810A-812A
DESCRIPTION	Flatbed plotters	Drum plotters	Plotter	Plotter	Plotters	Plotters	X-Y Plotter	X-Y Plotter	X-Y Plotters
TABLE									
Plotting area	31"x34 48"x78"	12" width 30" width	60"x60"	45"x60"	48"x60" to 60"x288" Tilttable Horizontal (Model 32)	48"x60" to 60"x228" Tilttable	30"x30"	30"x30"	11" width 29½" width
Vertical/ horizontal	Vertical/ horizontal	—	Vertical (fixed)	Horizontal (fixed)	—	—	Vertical (fixed)	—	—
AXES									
Number	2	2	2	2	2 to 5	2 to 5	2	2	2
X&Y reversal	—	Yes	—	—	Yes	—	—	—	—
Axis offset	—	—	—	—	Yes	Yes	Yes	Yes	—
SMALLEST PLOTTING UNIT	0.01"	0.005" 0.010"	0.0004"	—	0.00001"	0.00001"	—	—	0.005" 0.010"
ADJUSTABLE SCALING FACTORS									
ACCURACY	—	—	±.0002" (point)	0.050" (point) 0.015" (line)	±.0006"	±.001"	±.001"	±.001"	—
REPEATABILITY	—	—	±.0001"	—	±.0003"	±.0005	±.0006"	±.0006"	—
VACUUM HOLD	—	—	Yes	Yes	Yes	Yes	Yes	Yes	—
INPUT MECHANISMS									
Keyboard	—	—	Yes	Yes	Yes	Yes	Yes	—	—
Punched tape	—	—	RCA 501 code	5, 6, 7, or 8 level	EIA 8 channel	EIA 8 channel	7 or 8 level	—	—
Punched card	—	—	IBM 514	IBM	IBM	IBM	4066C	—	—
Magnetic tape	IBM	IBM	—	IBM	IBM	IBM	IBM	—	—
Other	200/556/800 bpi On-line computer	200/556/800 bpi On-line computer	—	200/556 bpi Analog inputs	200/556/800 bpi On-line computer	200/556/800 bpi On-line computer	200/556 bpi On-line computer	—	On-line computer
MAX. PLOTTING SPEED	90/180 inches/sec.	105/135/210/270 inches/sec.	50 inches/min. (25-2" line segments)	4500 points/min.	Up to 750 inches/sec.	—	75 inches/min. (300-0.025" line segments)	1200 inches/min. 1500 pts./min. (Model A) 75"/min. (Model D)	90-180 inches/min. (18,000-0.005" line segments)
SYMBOL PRINTER	—	—	Rotatable 200° 11 symbols	Yes 48 symbols	Yes	Yes	360 char./sec. 50 symbols	360 char./sec. 50 symbols	—
SYMBOL GENERATOR	—	—	—	—	Yes Up to 16X enlargement	90° rotate Up to 16X enlargement	—	—	—
DASHED-LINE GENERATOR	—	—	—	—	¼" & ⅛" with ⅛" & 1/16" spacing	Yes	—	—	—
CIRCULAR	—	—	—	—	—	Yes	—	—	—
INTERPOLATION OUTPUT									
Paper	Yes	—	0.003"-0.020" thickness	Yes	—	—	—	—	—
Scribe cote	Yes	—	—	—	—	—	—	—	—
Paper roll feed	—	120 ft. length	Yes—Automatic 0.015" accuracy	—	—	—	—	—	—
PEN TYPES	Pens; Ball point; Scribes	—	—	Pens; Ball point; Scribes	Pens; Ball point; Scribes; Light pen	—	—	—	—
MODES	Incremental (1" max.)	Incremental (½" or 1" max.)	—	Incremental (5" max.)	Absolute Incremental	Absolute Incremental	Incremental (0-10" max.)	Incremental (0-10" max.—Model D)	Incremental (½" or 1" max.)
SPECIAL FEATURES	—	24 basic step directions	—	—	Sequence number display and search	Up to 32K core memory available	Also accepts analog inputs; Magnetic tape file search	Dual arm 4-pen recorder for simultaneous plotting of 2-input sources from an on-line digital computer (Model D)	—
COMMENTS	Magnetic tape search speed is 60 in./sec.			Model A displays analog inputs.				Unit can be located up to 50 feet away from computer.	

GRAPHIC RECORDERS (MANUAL CURVE FOLLOWERS)

MANUFACTURER	Aristo Unitech Corp.	Auto-Trol	Auto-Trol	Auto-Trol	Benson-Lehner	Benson-Lehner
MODEL	8840/8850	3400	3929	3700 Series	099D	Larr-VH
RECORDING CHARACTERISTICS						
Resolution	0.0001"	0.001"	0.001"	0.001"		0.001"
Accuracy	0.0003"	0.004"	0.008"	0.010"	0.01"	0.01"
Selectable Increment	—	8 position 0.001" to 2.00"	0.001" to 0.004"	—	—	—
Format Control		Patch panel		Patch panel	Patch panel	Patch panel
Reverse Axis	—	Yes	Yes	—	—	—
Axis Offset	Yes	Yes	Yes	—	—	—
SPEED						
Operator Limited Discrete Points	8 points/min.	16 points/min.	8 points/min.	8 points/min.	8 points/min.	8 points/min.
Continuous Tracing	6 inches/min.	12 inches/min.	6 inches/min.	6 inches/min.	6 inches/min.	6 inches/min.
Recording Media Limited Based on 500 CPS Magnetic Tape	—	50 points/sec. (5 counts/coordinate)	—	—	—	—
On-Line Computer Connection	—	Yes 10,000 counts/sec.	—	—	—	—
TABLE CHARACTERISTICS						
Size	31" x 39" 79" x 102"	24" x 36"	44" x 60"	44" x 60"	16" x 24"	48" x 60"
Paper Roll Feed	—	Yes	—	—	Yes	Yes
KEYBOARD CHARACTERISTICS						
No. of Keys	—	18-30	—	18	—	—
Thumbwheels, etc.	—	15	Yes	15	12	—
Record Counter	—	4 digit	No	2, 4, or 6 digit	4 digit	—
OUTPUTS						
Magnetic tape	—	200/556 incr.	200/556	Yes	200/556 incr.	200/556 incr.
Punched tape	Yes		—	Yes	—	—
Punched card	—	Yes	Yes	Yes	Yes	Yes
Other	Page printer	—	—	Page printer	—	—
FILM PROJECTOR	—	Optional	—	Yes	—	—
OPTIONAL PENCILS	—	No	No	—	4	—
COMMENTS				Will digitize on time-sharing basis with up to 6 remote points		

GRAPHIC RECORDERS (MANUAL CURVE FOLLOWERS) (Cont'd.)

MANUFACTURER	Benson-Lehner	Calma	Concord Controls	Data Equipment Co. Bolt, Baranek & Newman	Edwin Industries
MODEL	Larr-D	302	Floating Arm Recorder	Grafacon 1010	Pencil Follower
RECORDING CHARACTERISTICS					
Resolution	0.004"	0.010"	0.010"	0.01"	0.004"
Accuracy	0.004"	0.012"	0.005"	0.01"	0.004"
Selectable Increment	—	No	0.01" to 0.25"	—	No
Format Control	Patch panel	—	Programmed	—	Patch panel
Reverse Axis	—	—	Yes	No	No
Axis Offset	—	Yes	Yes	No	Yes
SPEED					
Operator Limited Discrete Points	8 points/min.	16 points/min.	16 points/min.	16 points/min.	16 points/min.
Continuous Tracing	6 inches/min.	12 inches/min.	12 inches/min.	12 inches/min.	12 inches/min.
Recording Media Limit Based on 500 CPS Magnetic Tape	—	500 points/sec. (1 count/point)	See comment below	—	60 points/sec.
On-Line Computer Connection	—	—	See comment below	Yes	Yes
TABLE CHARACTERISTICS					
Size	48" x 51"	18" x 24"	30" x 30"	10" x 10"	18" x 40" 40" x 40"
Paper Roll Feed	—	Yes	No	No	Yes
KEYBOARD CHARACTERISTICS					
No. of Keys	—	—	—	No	16-30
Thumbwheels, etc.	—	—	—	No	10
Record Counter	—	—	Variable	—	4 digit
OUTPUTS					
Magnetic Tape	200/556 incr.	556 incr.	556	No	200/556 incr.
Punched Tape	—	Yes	Yes	No	Yes
Punched Card	Yes	—	Yes	—	—
Other	—	—	—	Computer	—
FILM PROJECTOR	—	Yes	Yes	—	—
OPTIONAL PENCILS	—	—	—	No	Yes
COMMENTS		Incremental digitizer; 0.01" increment	Uses computer control with core memory buffer -- very flexible		

CRT CONSOLES (ALPHA AND VECTOR)

MANUFACTURER	BUNKER RAMO*	CONTROL DATA	CONTROL DATA	CONTROL DATA	DIGITAL EQUIPMENT CORP.	DIGITAL EQUIPMENT CORP.
MODEL NO.	TRW-85	DD40	Digigraphic 270	280 System	30	340
PRODUCT DESCRIPTION	—	—	—	282 Display console	Point Display	Incremental Display
CRT CHARACTERISTICS						
TUBE SIZE	23"	16"	22"	19"	16"	16"
SPOT SIZE	—	—	0.015"	—	0.030"	0.030"
BRIGHTNESS	—	—	—	—	—	—
ACCURACY	—	—	—	—	+ 3% of raster	—
PHOSPHOR	—	—	P-7	—	—	—
STABILITY	0.5% in 8 hrs	—	+ 0.05" in 8 hrs	—	0.5% in 8 hrs	0.5% in 8 hrs
DEFLECTION SYSTEM	Magnetic and Electrostatic	Electrostatic	Magnetic	—	Magnetic	Magnetic
GRAPHIC CHARACTERISTICS						
DISPLAY AREA	12"x16"		14"x14"	11 1/2"x11 1/2"	9 3/8"x9 3/8"	9 3/8"x9 3/8"
GRID SIZE	512x384	1024x1024	4096x4096	1024x1024	1024x1024	1024x1024
POINT PLOTTING SPEED	—	—	25 usec	—	50 usec/point	35 usec/point
VECTOR PLOTTING SPEED	3" length in 50 usec	—	1.67 usec for 1/4" length	—	Point plotting only	1.5 usec.
IMAGE REGENERATION RATE	30 to 60 times/sec	40 times/sec	30/sec	60/sec	Variable	Variable
CHARACTER GENERATION						
NO CHARACTERS	64	128	—	—	—	128
TYPE OF GENERATION	—	—	—	—	Dot	Dot
RATE OF GENERATION	100,000 char/sec	125,000 char/sec	—	—	20,000 char/sec	30,000 char/sec
SIZE OF CHARACTER						
CONTROL FUNCTIONS						
BUFFERING	4096 words	2048	120,000 Byte Drum	Yes in Model 280 control	One point	One point
LIGHT PEN	Yes	Yes	Yes	Yes	Optional	Yes
KEYBOARD/STATUS DISPLAY	Yes	—	Yes	Yes	Status-2 rows of 10 lights	Status
AUXILIARY OUTPUTS	—	35mm. film	—	—	16mm. film	—
COMMENTS		Resolution is 50 lines/inch.	Resolution is 1/1000			

CRT CONSOLES (ALPHA AND VECTOR) (Cont'd.)

MANUFACTURER	EAI	IBM	INFORMATION DISPLAY INC.	INFORMATION DISPLAY INC.	INFORMATION DISPLAY INC.	INFORMATION DISPLAY INC.	SDS
MODEL NO.	8880	2250	M 11000	M 11000	M 10000	M 10000	
PRODUCT DESCRIPTION	Analog Display	—	Standard Monoflec	High Speed Monoflec	Standard Dualflec	High Speed Dualflec	—
<u>CRT CHARACTERISTICS</u>							
TUBE SIZE	14"	21"	21"	21"	21"	21"	—
SPOT SIZE	0.040"	0.018"	0.01"	0.01"	0.01"	0.01"	0.020"
BRIGHTNESS	—	—	20 ft.-lamberts	20 ft.-lamberts	20 ft.-lamberts	20 ft.-lamberts	—
ACCURACY	—	—	+ 3% of full scale	—			
PHOSPHOR	P-31	P-7	P-31	P-31	P-31	P-31	—
STABILITY			0.5% in 8 hrs	0.2" in 8 hrs			
DEFLECTION SYSTEM	Electrostatic	—	Magnetic	Magnetic	Magnetic & Electrostatic	Magnetic & Electrostatic	—
<u>GRAPHIC CHARACTERISTICS</u>							
DISPLAY AREA	8"x11"	12"x12"	12"x16" 15" dia. 13"x13"	12"x16" 15" dia. 13"x13"	12"x16" 15" dia. 13"x13"	12"x16" 15" dia. 13"x13"	10"x10"
GRID SIZE	—	1024x1024	1024x1024	1024x1024	1024x1024	1024x1024	1024x1024
POINT PLOTTING SPEED	—	—	50 usec/point	14 usec/point	50 usec/point	14 usec/point	20 usec/point
VECTOR PLOTTING SPEED	—	16 usec.	150 usec full screen	50 usec full screen	150 usec	50 usec	40 usec
IMAGE REGENERATION RATE	—	30 to 40 times/sec	30/sec	30/sec	30/sec	30/sec	—
CHARACTER GENERATION							
NO. CHARACTERS	—	64	N/A	N/A	71	71	—
TYPE OF GENERATION	—	Stroke	N/A	N/A	Stroke	Stroke	—
RATE OF GENERATION		66,000 char/sec	N/A	N/A	14,000/sec.	100,000/sec.	12,500 char/sec
SIZE OF CHARACTER	—	—	—	—	—	—	—
<u>CONTROL FUNCTIONS</u>							
BUFFERING	—	Yes	Yes	Yes	Yes	Yes	—
LIGHT PEN	—	Yes	Yes	Yes	Yes	Yes	Yes
KEYBOARD/STATUS DISPLAY	Keyboard and status	Keyboard and status	Yes	Yes	Yes	Yes	—
AUXILIARY OUTPUTS	—	—	Yes	Yes	Yes	Yes	—
COMMENTS	Accepts up to 18 analog inputs						

DOCUMENT READERS

MFGR.	MODEL	DESCRIPTION	SPEED		DOCUMENT TYPE AND SIZE	CHARACTER SET	TYPE FONTS	OUTPUT MEDIA	COMMENTS AND OPTIONS
			Max. Char/Sec	Max. Documents/Min					
Burroughs		Typed page reader	75	10	8 1/2" x 11"	Letters Numerals Punctuation	Standard elite (U.C.)	—	
Control Data	915	Page reader	370	180	Typed copy 2 1/2" x 4" to 4" x 12"	Alphanumeric Punctuation	—	Computer	Mark sense Edit symbols
Farrington	3030	Page scanner	400	2	Typed copy 4 1/2" x 5-5/8" to 8 1/2" x 13 1/2"	Letters Numerals Special marks	Selfchek 12 F/L	Magnetic tape Punched cards Punched tape	Mark sense Stored program control Very flexible
Farrington		1D document reader	330	440	2, 2" x 2" to 8 1/2" x 6"	Letters Numerals Special marks	Selfchek 12 F/L	Computer Magnetic tape Punched cards	Mark sense Edit symbols Reads 1 or 2 lines Checks, lists and accumulates
Farrington	3020/3022	Card reader	680	550	51 or 80 col. cards	Numerals	Selfchek 7B, 9B, 12 F/L IBM 1428E	Punched cards	Mark reading Format controls Checking
Farrington		Tape reader	1000	2880 lines/min	1-5/16" to 4 1/2" widths	Alphanumeric Special symbols	Selfchek 9B, 12 F/L IBM 1428	—	
IBM	1428	Optical reader	500	400	Paper or card 2-3/4" x 5-7/8" to 3-2/3" x 8-3/4"	Alphanumeric	IBM 1428	Computer	Mark reading Document sorting Reads 1 or 2 lines
IBM	1231	Optical mark page reader	550 marks	33	8 1/2" x 11" preprinted forms	Mark sensing	—	Computer	Selective reading of fields Checking
IBM	1418	Optical char. reader	500	420	2-3/4" x 5-7/8" to 3-2/3" x 8-3/4"	Numeric Special symbols	IBM 407, 407-1, 407E-1	Computer	Mark reading Document sorting Reads 1 or 2 line
IBM	1282	Optical card reader	2500	200	51 or 80 col. cards	Numerals 7 symbols	IBM 1428F, 1428EF, 1428ER Farrington 7BF, 7BR	Punched card	Mark reading
IBM	1285	Optical tape reader	365	2190 lines	1-5/16" to 3 1/2" widths	Numerals Special symbols	IBM 1428 NCR NOF	Computer	Bad line marking Operator correction of bad characters
IBM	1287	Optical reader	375	2250 lines	2 1/4" x 3" to 5-7/8" x 9"	Numerals Special symbols	Hand printing IBM 1428, ASC- SOCR, NCR NOF, Farrington 7B	Computer	Mark reading Tape reading Reads 485 printed documents/min. or 170 hand printed documents/min.
NCR	420	Tape reader	832	1560 lines	1-5/16" to 3 1/4" width	Numerals Special symbols	NCR Selfchek	—	
UNIVAC	—	Readatron	580	200	Credit cards	Numerals	No. 281	—	
Philco	—	Page reader	2000	360	3" x 5" to 8 1/2" x 11"	Alphanumeric Special symbols	—	—	
RCA	5820	Character reader	1500	1000	2 1/2" x 2 1/2" to 4" x 8 1/2"	10 numerals 5 symbols	RCA N-2	—	
Recognition Equipment	—	Page reader	2400	1200	2" x 2" to 5" x 8-3/4" Typed copy	Alphanumeric Special symbols	Multiple	—	
Recognition Equipment	—	Tape reader	2400	1800 lines	1-5/16" to 6" widths	Alphanumeric Special symbols	Multiple	—	
Recognition Equipment	—	Character reader	2400	30	3.25" x 4.88" to 10" x 14"	Alphanumeric Special symbols	Multiple	—	

CRT CONSOLES (ALPHA, VECTOR, & OPTICAL)

MANUFACTURER	BUNKER RAMO	STROMBERG-CARLSON	TASKER
MODEL NO.	BR-90	SC 1090	9000
<u>CRT CHARACTERISTICS</u>			
TUBE SIZE	—	19" Charactron	23"
SPOT SIZE	.02"	—	0.015"
BRIGHTNESS	20 ft.-lamberts	20 ft.-lamberts	100 ft.-lamberts
ACCURACY	—	—	0.5%
PHOSPHOR	P-4	—	—
STABILITY	1% of full scale	0.015" spot movement	
DEFLECTION SYSTEM	Magnetic		Electromagnetic High speed
<u>GRAPHIC CHARACTERISTICS</u>			
DISPLAY AREA	13.2"x13.2"	—	13"x18"
GRID SIZE	512x512	—	—
POINT PLOTTING SPEED	—	—	Random position (4usec)
VECTOR PLOTTING SPEED		2" in 80 usec.	1usec for 3/4" Vector
IMAGE REGENERATION RATE	60 times/sec.	30/sec.	60 times/sec.
CHARACTER GENERATION			
NO. CHARACTERS	63	64	64
TYPE OF GENERATION	Stroke	Shaped Beam	Stroke
RATE OF GENERATION	200,000 char/sec	30,000 char/sec	250,000 char/sec
SIZE OF CHARACTER	0.13"x0.10"/ 0.26"x0.20	—	0.1"x0.1"/ 1.5"x1.5"
CONTROL FUNCTIONS			
BUFFERING	Yes	Optional	—
LIGHT PEN	Yes	Yes	Yes
KEYBOARD/ STATUS DISPLAY	Yes	—	Yes
AUXILIARY OUTPUTS	—	Film projector	—
COMMENTS	Circle generator; Slide capacity is 5 magazines of 70mm. slides.		Displays 4000 char.

SUMMARY OF CHARTS ON GRAPHIC DATA SYSTEMS AND DEVICES

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EDP FORMS TECHNOLOGY

It is commonly recognized that when the forms industry ran head-on into computer technology, it would never be the same again. Overall volume, product mix, manufacturing methods, and marketing were all profoundly affected. What is often overlooked, is the importance of forms technology to EDP. Both computer manufacturers and computer users have paid too little attention to the mundane business form. And both are unwittingly paying a price.

Some areas of impact are obvious, such as the mechanical demands variable paper media have made upon line printer design. In the face of a trend from the mechanical to the electronic, the computer line printer remains in large part mechanical. Hence, from a cost engineering standpoint, and its field maintenance needs, the printer remains one of the more critical peripherals.

Just as significant is the connection between form design and effective printout speed. The typical line printer can write out a 132-character line just as fast as a ten-character line. It uses nonproductive milliseconds skipping over "white space" on the form. Printer specifications normally give optimum speed, which in reality is seldom realized. Both vertical and horizontal form layout have a strong impact upon how much of the printer's potential speed is actually used.

Coordinating form sizes and layout with the machine room scheduling can yield significant savings. Proper planning can minimize the need to change carriage control tapes, plugboards, tractor positioning, and other operator controls. Using compatible form sizes and formats can help minimize delay between jobs and operator attention during the run.

When a form jams in the printer, it is certainly not the value of the mutilated form which is of concern. Nor is it necessarily any attendant computer downtime. The major cost is reconstructing the page or pages of information involved. If the forms are consecutively numbered, such as checks, the problem is worse. If it is a small system where printout is on-line from a disc file, there may be still another dimension to the problem. Unless some special precaution is taken, re-running could cause part of the file to be ruined by being updated twice.

THE BIGGER PICTURE

All the above considerations have direct bearing upon overall computer system throughput. But such considerations may not be the only ones, or even the major ones. In all honesty, it can be stated that both forms salesmen and forms buyers often put too much stress on machine efficiency without taking into account the bigger picture.

For instance, with the emerging pre-eminence of "image", some companies are using more and more custom forms. This means a form change with each job. Forms should be "conditioned" in the machine room, or in an area with identical atmospheric

conditions. Delivery of custom forms may be as long as three or four weeks. This all adds up to a really significant problem in form storage and inventory control.

Then there is the obvious factor (which is often overlooked) - the cost of the form itself. Continuous forms are not cheap. In the most common sizes, the cost can range from several dollars a thousand for singles, to \$80 or \$90 a thousand for six- and eight-part sets. The 1000-line-a-minute printer can run through such forms at 20 or so a minute. With moderate usage, one line printer can, therefore, use \$50,000 to \$75,000 worth of forms a year.

Most line printers do not consume this volume, although some exceed it. Surveys indicate that the average line printer consumes about \$10,000 per year in forms. But it is obvious that the cost of the forms per year sometimes approaches the value of the hardware itself, and it often exceeds its rental. So in a business data processing operation, forms cost can be a very real factor in the financial balance sheet.

At one time, "use cost" was many times the forms cost, but this is now almost a cliche. Yet one that is expensive to ignore. In most cases, what happens to the form after it is written by the computer really tells the tale of whether the form is doing its job or not. "Afterhandling" operations, such as bursting and decollating, can be a problem but there is much more. Does the form perform its "end use" job effectively? Is the impression sharp and intense on all copies? Does the message come through loud and clear? Will it stay that way as long as it could possibly be needed? Form specifications that enable the form to meet these demands are much more important than those which relate to its efficiency in the computer printer. The printer is only a means to an end.

Surrounding the computer itself is a much larger complex, composed of forms which are not physically passed through the computer printer. The value of these forms - both in their cost and the office work involved in their use - is often much greater than the continuous forms used in the computer itself. But the design of all these forms, especially those leading up to the generation of computer input, should be closely linked to the EDP operation. Large savings can be garnered by replacing home-made "flat" forms with well-designed unit set forms. Although the scope of this article is not broad enough to treat these peripheral forms, it should be stressed that they are an important part of EDP forms technology, and should not be ignored.

Most important, in business applications, the form should be viewed, for proper perspective, as the final end product. The written form carries information not only within the company, but often also to the public. Here is where computer users are sometimes penny-wise and dollar foolish. Attractively-printed and clearly-written forms are probably the biggest bargain available from the "end use" standpoint. Compared with the cost of systems planning, hardware, programming, and operation of the EDP system which produces these documents, the cost of

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the document itself is very small. This is why some organizations are using forms made of better materials than the line printer demands. It is why many forms are being printed in two or three colors. Size and layout might be such that effective line printer speed is far below its optimum. Yet the intangible benefit derived from the impact of the document upon the human being for which it was designed more than compensates for the added purchase and document preparation cost.

Demands placed on forms by EDP—both from the standpoint of performance in the computer printer and this bigger picture—are complex, and sometimes contradictory. It is the challenge which EDP poses for the forms industry. Computer users will be better qualified in dealing with forms vendors, and assessing their capability to meet these needs once they have acquired some knowledge of the nature of the forms industry.

YESTERDAY'S PAPERWORK CRISIS

The forms industry was born out of the pioneering efforts of certain inventors almost a century ago. The second half of the nineteenth century was characterized by rapid growth in industry and commerce. And the rapid growth of that day caused a counterpart of today's paperwork "crisis".

One of the main problems was getting more than one copy with a single writing. Documents were often rewritten. The alternatives were cumbersome and probably messy. Writing was with indelible pencil and copies were made by a complicated transfer process using dampened tissue and pressure. Another method involved writing through an ink-impregnated cloth to obtain one relatively crude copy.

The Carter Salesbook, patented in 1881 by Toronto department store clerk J. R. Carter, is cited by some as the beginning of the forms industry. This writing "system" is said to have been the first to incorporate the following features: carbon paper ("blackleaf") bound into the stub, consecutive numbering, and special cover. Forms had been printed for many years, but this was something new. It yielded an additional copy with one writing (so it was considered a "manifold" form). Carter went to a printer, Samuel Moore, to manufacture his salesbook, and the result, of course, was the beginning of today's giant of the forms industry, Moore Business Forms.

Other inventions followed close on the heels of the salesbook. In 1882, a Major Shoup developed a mechanical "autographic" register, which produced "manifold" forms with one writing. It used a continuous form, ensured sequential control, and offered a convenient writing surface. Shoup founded Autographic Register Company, and this firm is still headed by a Shoup and is a major forms manufacturer. Similar writing devices were developed by other firms. Egry Register Company was one, which is now part of Allied Paper Company's forms operation.

Standard Register Company developed a pinfeeding register, and was soon producing marginally-punched forms for not only its registers, but for other office machines as well. Around the turn of the century, special roll-to-roll presses were invented to mass-produce register and other continuous forms. Onetime carbon paper began to be manu-

factured by Moore, Pacific Manifolding Book Company, and other firms in the immediate post World War I years. This opened the way for the familiar unit set form, often called a snapout form (although the term "snapout" should not be used in the generic sense, since it is a registered trade name of the Snapout Forms Company).

By the end of the 1920's, all the key products and features of today's forms industry had been developed: high speed roll-to-roll presses, one-time carbon paper, autographic registers and salesbooks, marginally-punched continuous forms, and unit-set forms. Most of today's major firms had been well established. Yet, it took World War II to set into motion the forces which have produced the modern forms industry.

The War imposed unprecedented demands upon administrative paperwork in both industry and government. There was a huge military and defense production logistics problem. Administration of price controls, wage controls, war production priorities, and consumer goods rationing made big demands on paperwork. And, at the same time, there was a manpower shortage, especially for such "unproductive" functions as paperwork.

It was essential that more closely controlled administrative "systems" be set up, and the concepts of "paperwork management", "forms control", and "work simplification" were born. At the same time, machine accounting became widespread, increasing the demand for continuous forms. And finally, the War created the impetus for the development of the electronic digital computer. When computers finally became accepted as a business tool, they placed new demands on the forms industry, and were responsible for its spectacular growth.

FORMS INDUSTRY SNAPSHOT

It was not until 1958 that the Department of Commerce made the forms industry "official" by assigning a product code to "manifold business forms" (S.I.C. 2761), and taking the first survey of the industry. Hence, most figures on business forms growth begin in 1958, and most analyses of the products correspond with the categories identified by the Bureau of Census.

It is well to keep in mind that "forms industry" normally refers to the manifold forms industry. There are probably many times the volume of non-manifold forms produced in the United States—these "flat forms" are spewing forth continually from the duplicators and small presses of thousands of company reproduction departments and small commercial printers. And although some may guess, no one really knows the total volume represented by this kind of form.

But the manifold form is a specialized and distinct product. To manufacture it efficiently, expensive equipment is needed. Hence the industry is not difficult to identify, and the government volume figures for S.I.C. 2761 are, no doubt, fairly accurate.

Other statistics are collected by the major industry association serving the forms industry—the Business Forms Section of the Printing Industries of America, Inc. This association was founded in 1953 and has now grown to include most

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of the major manufacturers. From these two sources of statistics, the business forms growth figures shown in Table I have been derived.

As would be expected, between 1958 and 1966 continuous forms have grown faster than unit forms. But the difference is not nearly as great as some people expected when it became apparent that much of business paperwork was going to be computerized. To their surprise, unit-set growth accelerated also. Part of the reason is the "broad base" of small businesses that are just becoming aware of the efficiency of the "snap-out" type form. But a more important reason may be that when a large firm undertakes analysis in preparation for installing a computer, systems people look at all paperwork critically for the first time. As a result, many flat forms are combined into unit sets, with resultant savings.

Table 2 lists the major manufacturers of business forms. Bureau of Census statisticians say they "like" the forms industry since it is relatively "pure". The lion's share of the total volume is produced by firms which manufacture forms almost exclusively. But the third part of the list (major forms producers whose major product is not forms) represents a group that may disrupt this pattern. With the ever-closer inter-relationship between EDP hardware and forms, it is expected that hardware manufacturers may increase their interest in marketing forms.

Table 3 shows that the largest firms dominate the industry. Moore is by far the largest, with about a quarter of the market. Although the larger firms tend to be among the fastest-growing and also show the highest profits, during the last fifteen years they have not maintained their concentrated

share of the market as is the case with the leading firms in many other industries. In fact, there is evidence the reverse has happened. Increasing specialization of commercial printers in forms, new firms coming into the industry, and the increased emphasis of non-forms firms has caused total forms production to expand faster throughout the industry as a whole than it has among the leading firms. It has been estimated that in 1952 Moore represented about 33% of the total market, and the "big three" represented 55%. However, these shares have tended to dwindle since that time.

BUSINESS FORMS DISTRIBUTION

Three major sources exist for forms: manufacturers' direct salesmen, independent distributors, and stationers or office supply houses. It is important for forms buyers to know that these alternatives exist. Each has its own advantages. And a lot of misunderstandings can be avoided if the buyer is aware of the kind of forms vendor with which he is dealing.

Only the largest 8 or 10 forms manufacturers can support a nationwide sales force. By working with a direct salesman, the user can normally be assured of a product of consistent quality from one order to the next. The forms are "brand name" products, which means he knows where they came from, and that the reputation of a relatively-large corporation rests on the quality of the product. Direct salesmen tend to be knowledgeable, well qualified to offer advice on a forms design and construction best fitted to a specific business problem and the printout devices being used. Most

Table 1 • Market Growth For Major EDP Forms

	\$ VOLUME IN MILLIONS							
	1958	%	1963	%	1966 (Estimate)	%	% Increase since 1958	
STOCK CONTINUOUS FORMS	18.8	5	54.0	9	120.0	15	538	
ALL OTHER CONTINUOUS (Includes custom, imprinted stock forms, fanfold and autographic register forms)	150.4	40	237.1	40	310.0	37	106	
UNIT SETS (all)	159.5	43	257.9	43	348.0	42	118	
OTHER (Salesbooks, specialized flat forms, and misc.)	45.2	12	49.4	8	52.0	6	15	
Total	373.9	100	598.4	100	830.0	100	122	

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Table 2 • Major Forms Manufacturers in USA (Manifold Forms Only)

FIRM	APPROX. SALES*
	\$ MILLIONS
(Publicly-held manufacturers)	
Moore Business Forms, Inc., Niagara Falls, N.Y.	241.3
Standard Register Co., Dayton, Ohio	72.4
Uarco, Inc., Barrington, Ill.	59.4
Reynolds and Reynolds, Dayton, Ohio	24.1
Wallace Business Forms, Chicago, Ill.	21.6
Ennis Business Forms, Ennis, Texas	17.5
Lewis Business Forms, Jacksonville, Fla.	11.8
Baltimore Business Forms, Baltimore, Md.	11.3
American Business Systems, Philadelphia, Pa.	5.4
Demarco Business Forms, Philadelphia, Pa.	4.4
Royal Business Forms, Nashua, N.H.	2.6
(Other major manufacturers)	
Philip Hano Company, Holyoke, Mass.	
Adams Business Forms, Topeka, Kans.	
Snapout Forms Company, Chardon, Ohio	
Autographic Business Forms, S. Hackensack, N.J.	
Bonnar-Vawter, Inc., Keene, N.H.	
Courier-Citizen Co., Uniform Printing & Supply, Lowell, Mass.	
Graphic Controls Corp., Buffalo, N.Y.	
Shelby Business Forms, Shelby, Ohio	
(MAJOR MANUFACTURERS WITH FORMS MANUFACTURING DIVISIONS)	
PARENT COMPANY	FORMS SUBSIDIARY OR DIVISION
National Cash Register	Business Systems, Inc., Los Angeles, Cal
Burroughs Corporation	Todd Division, Rochester, N.Y.
Bell & Howell (Ditto Div.)	Southern Business Forms, Knoxville, Tenn.
Litton Industries	McBee Systems, Greenwich, Conn.
Litton Industries	Sturgis-Newport Business Forms, Sturgis, Mich.
Litton Industries	Eureka Carlisle Co., Scranton, Pa.
IBM Corporation	Information Records Div., Princeton, N.J.
Allied Paper Corporation	Allied/Egry Business Systems, Dayton, Ohio
Victor Comptometer	Victor Business Forms, Lincoln, Nebr.
General Electric	Maqua Company, Schenectady, N.Y.
American Bank Stationery	Forms, Inc., Willow Grove, Pa.

* approximate sales for last fiscal year reported as of 12-66, for all products (business forms and other items); Moore sales are for U.S.A. and Canada.

EQUIPMENT CHARACTERISTICS REVIEW

of the large manufacturers have good salesman training programs and support their people with detailed information on data processing equipment. And, often, the manufacturers offer certain services which distributors cannot.

The manufacturers who cannot support such a sales force rely upon independent distributors. Many sell direct, locally or regionally, and through distributors outside that area. Others sell exclusively to distributors by choice. Some of these are quite large, such as Ennis Business Forms.

The most important thing to remember about independent distributors is that they can vary a great deal in their reliability as a forms source. There are estimated to be as many as 9000 forms "dealers" nationwide, who account for 20% to 25% of the total volume. Many work as individuals using their homes as offices. Some are larger and may have several salesmen. The distributor segment of the industry has its own association, National Business Forms Association (NBFA), and the distributors who belong tend to be the larger and better informed. Obviously there are some good distributors who are not members, and membership is not *prima facie* assurance of reliability. But in general, when considering whether to purchase forms from a distributor, NBFA membership should be taken into consideration.

Many distributors are alert and enterprising small businessmen who got their forms training as a direct salesman with one of the major manufacturers. They offer the advantage of being local businessmen; they are not shifted around the country, and will be more likely to get to know customers personally and become acquainted with a firm's specific problems. They are not restricted to a single factory, and theoretically can seek out the best source for each product. This might mean lower cost forms and better delivery. On the other hand, no single factory is tied to him, and sometimes he can have

a harder time holding his selected source to given delivery and quality. In general, the distributor should be judged on his individual merits and to what degree he qualifies as an *established* forms source. Those who pass this test can often be an effective supplier of some or all forms products.

It is important to face up to the fact that some forms salesmen are less than responsible, and some, perhaps, less than ethical (this might apply to some direct salesmen as well as independent distributors). But the forms buyer is not blameless. The problem stems in large part from poor buying habits of many forms users. One of the big unresolved problems in the forms business is protection of a salesman's investment in system study and forms design for a customer. Forms are seldom copyrighted. In this day of photo-offset lithography, most forms can be copied and reprinted at a fraction of the cost of creating the original. All too often forms buyers, under pressure from above to cut costs, will give re-orders to price-cutting competitors who will use the original forms as copy, once the creative design work is completed.

Re-orders are the only way a forms salesman can be adequately compensated for his advice and forms design effort. In the long run, it is best for both the forms user and forms supplier to make sure he receives this compensation.

COMPUTER HARDWARE CONSIDERATION

The forms requirements of computers are most directly prescribed by the technology of the line printer, whether it uses a flying drum, chain, train, or type stick. These devices depart from the earlier "tab" printers in the following ways.

1. Speeds have increased from 150 lines per minute to 1000 or more. The hammer dwell time of necessity must be much shorter. Furthermore,

Table 3 • Market Share — Manifold Business Forms Industry

ESTIMATED VOLUME— U.S.A. SALES, IN \$ MILLIONS, 1966	FIRMS	% of ESTIMATED 1966 TOTAL VOLUME
220*	Moore Business Forms	26.5
370	"Big Three" (Moore Standard Register & Uarco)	44.6
200	Next 23 firms, with annual sales volumes of over \$5 million	24.0
260	All other firms (approximately 450 firms)	31.4
830		

* Includes other than U.S. sales

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in all cases, the type element is constantly moving, so its impact on the paper is glancing rather than direct.

2. Impact is from the back of the form, rather than through the ribbon from the front.

3. The older "tab" printers have platens, and the form passes around the platen and is turned back on itself. High-speed printers generally do not require such contortions of the form; the path it takes through the machine is more direct.

4. Form advance is much more rapid. Whereas on the older IBM 407, paper skipping speed was 6 to 7 inches per second, on the IBM 1403, for example, it is 33 inches per second. And optionally, after 8 lines, skipping speed can be 70 inches a second.

5. To compensate for the absence of a platen which held the form tightly compressed, operator controls are normally more complete, and there are two sets of tractors rather than just one.

In addition, EDP seems to have brought with it the following more general requirements:

1. There seem to be more stringent copy requirements. Six- and seven-part forms have always been a fairly small minority of the total volume. But surveys show that there are more applications being set up with requirements for eight or more copies. So, in the face of lighter impact by the computer printer, the number of copies required has gone up.

2. Better quality copies are being demanded. When computers were a novelty, people seemed to have been willing to accept copies with marginal legibility. Now forms users expect something better. Or perhaps it is the increasing emphasis upon "image". Forms must not only convey a message; they must convey it with "style".

3. The sheer volume produced by a single high-speed printer creates problems in keeping a supply of the proper forms on hand, and decollating, bursting, and distributing the written forms.

IMPROVED MATERIALS

Among the major developments which have enabled forms to meet these demands is improved materials. There are now better bond papers, one-time carbon papers, carbonless papers, and duplicating masters.

Several mills have now made available relatively light-weight, (9# and 12#), smooth-finish papers, which often do not carry a premium price tag. Yet they are thin enough to carry an impression through seven or eight parts on some high-speed printers. The traditional "tab" form in the 6- to 8-part range would simply not yield that many legible copies in the newer printers.

But there are very distinct limits and dangers inherent in the lightweight papers. Opacity must be sufficient for good legibility; it must handle well in business forms manufacturing equipment; there must be enough strength to pass through the high-speed line printer; and it has to be rigid enough to re-fold properly after being written on, and during the decollating operation.

Sometimes, as a compromise for strength and ease of handling, lightweight plies are sandwiched between heavier weight "external" plies. However, since the hammers strike through the entire form against the moving type, any thick ply in the set reduces the write-through on all parts. So the thick final-ply, traditional with tab forms, is now avoided.

Although there is a lot of talk about carbonless papers, improvements in old fashioned carbon paper are just as significant. In general, high-speed printers require carbon on the hard side of medium, to minimize "framing" bleed when packed in the carton and smudging after the form is written. Better formulations have been developed which meet these needs, yet they provide sufficient intensity. Again, because of the light impact of computer printers, efforts are being made to reduce forms bulk by using lighter weight carbon paper. One of the major development efforts now going on is the search for techniques to coat lower grade, lightweight carbonizing base paper so as to reduce the price of the lightest weight carbon papers.

Thinner tissues and formulations with superior release, mated with new smooth-surfaced lightweight bonds, permit today's continuous forms to yield the extra copies many users demand in the face of the lighter impact of high-speed printers.

CARBONLESS PAPERS

Although the percentage is still small, carbonless papers are beginning to make some inroads in the continuous forms area. They offer the following advantages:

- Because there are no "interleaves", feeding through the printer is better;
- There is no "useless sheet" to take out and destroy after the form is written;
- There is no security problem posed by discarded carbon paper (which helps explain the heavy use of carbonless papers in government agencies such as CIA, AEC, and DOD departments);
- In some types the image is more permanent and less able to be altered than the carbon image;
- Some carbonless papers have less bulk, so more length can be packed into a carton, thereby reducing form changes or splicing;
- With self-contained carbonless papers, forms can be written without a ribbon;
- Certain types yield more copies than carbon interleaves.

Some disadvantages are:

- The form is usually more expensive;
- The blue image produced by some types is unacceptable in some applications, for example when it has to be copied or scanned;
- Some types yield fewer copies than carbon interleaves;
- The form is easily marred during handling before and after being written;
- Back printing may prevent an impression transfer in that area;
- "Desensitizing" or blocking out certain areas may be impossible or difficult;
- The types with a dark back coating prevent back printing;

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*The coatings or surface textures are considered objectionable in some applications.

There are two main types of carbonless paper: chemical and mechanical. NCR paper and 3M Brand Action Paper are the two chemical sheets now on the market. The former is a two-coat system, which offers the advantage of preventing further imaging after the parts have been separated. Action Paper is "self-contained" in that each part can be marked by pressure alone ("the ink is in the paper"). 3M Company also has announced its own "mated system" which is to compete directly with NCR Paper.

Mechanical-type carbonless papers may be either self-contained, transfer, or mated transfer papers. Self-contained papers include products such as Interchemical Dark Mark. This sheet has a dark substrate hidden by a light-colored "blush" coating. Upon impact, the surfact coating is compressed and rendered transparent, exposing the dark material beneath. With transfer papers, the pigmented coating is on the back of the sheet; when struck, it is transferred to the sheet behind. Examples of this kind of paper are Ennis Novo Script and Columbia Drion. In such a sheet, transfer is indiscriminate to any material which happens to be behind the paper. Finally, there are some mechanical transfer carbonless papers which have varying degrees of discrimination in the transfer. In other words, a special receptive front coating must be on the sheet below for image transfer. This kind of sheet is represented by Frye Impact Paper and Standard Packaging's ETC Paper (the latter is manufactured under other trade names throughout the world).

Most important, it should be remembered that the mechanical sheet is a completely different entity from the chemical, and has its unique advantages. By far the most important is high sensitivity and compactness. These features permit such materials to yield twice as many copies as the chemical sheets, and more than a conventional carbon interleaved form. The major applications, as would be expected, are when there is need for 8 to 10, or even more, copies.

Sometimes bond paper with a regular carbon coating directly on the back is considered a "carbonless" paper (in that there are no interleaves). For those who can live with the black carbon back coating, this is the least expensive carbonless type of form available. It also yields as many copies as the best kind of mechanical transfer carbonless papers. Two such bond papers are Port Huron Car/Bond and American Carbon Paper Company Taratab. The major application of this material is for reports which are bound, without being burst, so the carbon side is folded back on itself and cannot be seen or touched.

BEYOND TEN COPIES

When copy requirements go beyond ten or twelve parts, other solutions are necessary. Sometimes it is possible to print the form "two-up", with two identical forms side-by-side, which are slit apart after writing. This permits printout speed to be effectively doubled, or twice as many copies of the same information. Alternatively, the form can be

re-run. This permits non-premium materials to be used, and offers better quality copies. But more often, some duplicating or copying process will provide the answer.

One of the oldest duplicating materials is the continuous spirit master. Although often criticized for staining due to the powerful aniline dyes in the carbon backing sheet, new developments have given the spirit duplicating process new life. Sophisticated "systems" duplicators have been introduced which permit the operator to insert masters rapidly and copy forms of varying sizes, transferring variable information onto each. Setup is so fast that runs of six or eight are practical.

Secondly, new spirit carbon material has made the process a lot cleaner. "Bleed" of the powerful dye at the trimmed edges of the form, and where the cross-perforations are cut, has been a long standing complaint. Now spirit carbon is available with uncoated bands along the edges; at least one firm has developed a process to leave uncoated bands along the perforations as well. And finally, new "stainless", or non-water-soluble coatings are available that greatly decrease the staining problem.

Parallel developments have occurred in offset duplicating. Offset masters used to be rather thick and cost as much as 10¢ each. This meant running reports onto such material could be quite expensive. Now most manufacturers offer short-run, light-weight masters. They are thin enough so additional plies can be written beneath the master. And most important, the material is cheap, often below 1¢ for each form, which is little more than regular paper.

"Systems" offset duplicators are being successfully used in connection with many EDP operations. Their major features are simplified controls and easy master insertion, so short runs are efficient. Regular offset duplicators often required a fixed-size master. Systems duplicators handle "copy-size masters", which may range in size from as small as a 3 x 5 card to regular sheet sizes. This results in lower cost and more flexibility in form design.

The most sophisticated systems offset duplicators have two printing units. This permits a great deal of systems flexibility. For instance, blank continuous master material can be kept in the line printer all the time and with splicing, form changes are never required. The master with the "form" (or constant information) can be mounted on one duplicator unit, and the masters written by the computer mounted on the other. In this way the duplicator is reproducing both the form and the variable information together. Or with just one printing unit, this is still possible by pre-printing copy paper.

COPYING VS. DUPLICATING

Cheapest of the copying processes is diazo, the ammonia process long used for reproduction of engineering drawings. A special original is needed, but the only requirement for it is one-sided printing and a degree of translucency, so the cost is low. Diazo master material manufactured especially for business forms is sometimes called "general

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purpose bond". There have recently been introduced several diazo copying systems which can handle unburst continuous forms, under semi-automatic control.

In special situations other copying processes are used with business forms, such as infra-red, dye transfer, and electrofax. However, unlike Xerography, they do not offer features to compensate for a higher per-copy cost. Microfilming might be considered a copying approach, and this has long been used in connection with EDP-produced business forms. Recently, a microfilm camera was introduced especially for handling marginally-punched continuous forms. It was promoted with the slogan "Microfilming can be cheaper than carbon copies." When more widespread use is being made of micro-image storage and retrieval systems, it is probable more microfilming of forms will be done.

The major contender in the copying area, of course, is Xerox with its 2400 and 3600 copier-duplicator systems. What these machines lack in economy, they often more than make up for in speed, simplicity of operation, cleanliness, image permanence and quality, and flexibility. Transparent overlays or pre-printed and pre-collated copy paper can be used to reproduce constant information. Although it has developed some imaginative proposals for business systems using Xerography, Xerox considers its main market to be that already captured by offset and spirit duplicating.

The main advantages of the process, according to Xerox, are that the copying equipment is much easier to operate and chance of ruining data is less than with an offset duplicator. In general, computer users do not want an offset duplicator in their machine room and relegate such "printing" equipment to the reproduction department. The Xerox equipment, on the other hand, is said to be an acceptable accoutrement in the computer room and can be operated by unskilled personnel.

What is important is that in both copying and duplicating, per-copy cost and number of copies needed are often not the major consideration. Depending on circumstances, in the 8- to 15-copy range either a form set, or a copier, or a duplicator might be chosen to do the job, or a combination of these.

From the cost standpoint, the breakeven points differ widely anyway, depending whether the source is a forms, copier, or duplicator manufacturer. In connection with EDP printout, copiers are being widely used for producing extra copies which are exception cases, rather than building extra parts into the form which more often than not are discarded. Duplicators are most advantageous when the number of copies needed vary often, from form to form, or when copies must be made into different materials of varying sizes which would not easily combine into a set.

Both copying and duplicating are advantageous when a form is held in file, and additional copies are needed when information is added, as in some receiving report systems for multiple shipments. An additional operation is required after the form is written, but the copies produced are single, cut sheets, ready for distribution. And in both, image clarity and intensity is normally maintained, no matter how many copies are produced.

FORMS CONSTRUCTION FOR EDP

Construction features such as fastenings, perforations, narrow plies, or carbon are closely related to the line printer requirements, the end use of the form, and how the form is to be decollated and burst.

Normally the customer does not specify the perforations desired. There are too many variables here. Plants select perforating blades and wheels by long experience or by balancing out the following considerations: weight and quality of the paper, its grain, kind of carbon paper, whether the perforation will be made on press or collator, number of plies in the form, whether the ply is on the inside or exposed, the line printer with which it will be used, and how it will be burst (manually or by machine).

Sometimes customers do not specify fastenings, but they should. Knowledge of the kinds available and proper selection can spell the difference between success and failure in some applications. But it is essential that the forms supplier also be consulted, since some factories are not equipped to furnish certain fastenings.

There are four major choices when it comes to fastenings. The parts can be unfastened, they can be temporarily fastened, they can have permanent fastenings, or there can be a combination. Permanent fastenings can be either firm or flexible.

In most cases, cost is an insignificant consideration in the selection of fastenings. There is no additional charge for some. So the decision to leave a form unfastened should not be based on lower cost. There are advantages. One is that an unfastened form has margins which are free of cuts or foreign objects that can cause feeding problems in the printer and buildup on the margins when the form is flat-pack folded. Another is that after the form is written, removing the carbon and separating the parts is simplified.

It is generally recognized, however, that fastened forms feed better through a line printer than unfastened. Certainly above two or three parts some kind of fastening should be used. The fastened form is also easier to load into the printer, since the marginal punching maintains better alignment.

Crimping is a compromise solution which offers many of the advantages of no fastening and a permanent fastening. No foreign material such as glue or staples is introduced into the form. After writing, it can normally be easily pulled apart. However, crimps can vary widely in their holding power. The most relaxed kind of fastening, which might be considered a crimp, is Standard Register's patented "Stanlock". This is made by only partially cutting out some of the feed holes. When the form comes into the tractor of the line printer, the pins push these hanging punches through the form, which makes a loose crimp-like fastening to help hold the plies together during refolding at the line printer and during later handling.

The normal crimp consists of a set of small cuts through the form along one or both margins. Spacing may be as close as every two inches, or only one or two on each form. The lightest crimp has just three "fingers". For tighter gripping, there are others with four or five cuts on each, sets of opposing cuts, and crimps alternating from

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one side of the form to the other. Some of these types hold almost as tightly as staples, although with thick forms—five or more parts—the holding power of all crimps dwindles.

Depending upon how tight they are, crimps can have a number of advantages. Many plants have equipment that permits them to be made on the collator, so there is no upcharge. They permit the form to "flex", which is most helpful, as described below. Ideally, they are tight enough to hold the form in alignment (ply to ply) when it is being loaded into the printer, yet with mechanical decollators, can be pulled apart, obviating the need for special margin trimming attachments. One other kind of fastening which offers many of the same advantages is a rubber-cement-like adhesive called fugitive glue. Unlike crimping, this does not lose its holding power with thick formsets, and can be selectively applied to certain parts.

IMPORTANCE OF FLEX

Inserting a permanent fastening into a continuous form introduces the problem of flex. This can be appreciated by considering what happens in forms manufacturing, at the rotary collator. The marginal holes have been either punched on the press in each ply separately, then brought into alignment on the collator, or are punched through all plies together on the collator. In either case, with a five- or six-part form, picture what happens to the marginal holes when the form is folded back on itself during zig-zag folding. There will be internal pressure within the form to cause the holes to become staggered, since the inside ply will not travel as long a distance as the outside.

For many years, forms manufacturers had been accustomed to making unit-set forms by pasting along the stub. Most collators were therefore equipped with pasting attachments. But this paste did not set fast enough for continuous forms, allowing misalignment of the feed holes to be frozen into place after zig-zag folding. And when the form was straightened out the folds would not flatten, creating a problem called tenting.

Regardless of the alignment of the feed holes, another forms problem is associated with using a firmly-fastened form in a machine like a typewriter or tab printer. When the form is passed around the platen, once again it is turned back on itself, and internal stresses are created. Unless each ply can move a bit ("flex") to adjust to these pressures, there will be buckling and binding, and perhaps misfeeding.

When the form takes a more or less straight line path, as it does in high speed printers, this problem is avoided. So the requirement for fastenings are different. But for machines both with and without platens, there is today a fairly wide choice of permanent fastenings.

Fastenings like bumping, sewing, or the traditional staple offer the advantage of a slight amount of flex. However, all three of these fastenings tend to be more expensive than others, since to apply them is often a separate operation. Furthermore, many printer manufacturers warn against use of stapled fastenings in their printers. However, the newer, smaller staples, positioned so the long dimension lies perpendicular to the length of the form often

pose no problem. Care should be taken to make sure the fastened margin is clear of the ribbon and printing assembly.

The bump fastening and sewing are less common than the staples, and only a few manufacturers offer them. The danger of entering spurious metal into the printer is eliminated, and more flexing is possible. Sewing is with a thin nylon thread, normally on just one margin. The bump fastening consists of small tongues of paper cut out along one margin, which are locked by being folded back and passed through slits in the form. Because of the relatively low speed of machines to make these fastenings and added cost, they will probably not become common; they have been more widely used in Europe.

Pasting is the most widely-used permanent fastening for continuous forms. To overcome the problem described above, there have been developed hot melt gluing systems to apply glue that sets almost instantly, avoiding the slippage and tenting problem. Gluing may be either solid-line or spot. Solid line gluing can cause stiffness and curling in the fastened margin, which may interfere with feeding in the printer, and also can cause excessive buildup in the stacked pack.

Spot gluing has the advantage of using less glue, creating less buildup in the pack (if the spots are staggered), makes margins more flexible, and minimizes tenting.

Gluing of either type offers a number of unique advantages. If the form is to be fastened in one operation, most other fastenings require that the entire set be fastened together. But with gluing there is complete flexibility as to what is fastened to what. When certain parts are to remain together—as when mailing two parts of an invoice to the customer—these, and only these, need be glued, perhaps with a supplementary crimp holding together the entire set. In addition, special carbon extraction arrangements can be built into the form, and alternate margins can be glued for distributing buildup, enhancing flexibility, or making a double-stub set when the form has been burst. Although the gluing system for a collator is expensive, once installed, the running costs are low. Forms can be glued with little or no collator slowdown, so often there is no upcharge. The following are a few of the problems created by gluing.

1. Margins must be trimmed in order to separate the form.
2. The coated surface of the carbon paper sometimes interferes with the holding power of the glue.
3. It is a firm fastening which doesn't let the form flex. Flex is obviously important with machines having a platen. Some EDP users also feel flex assists in reliable form feeding in a line printer, since it lets the feed holes realign themselves when they reach the tractors.

FLEXIBLE PERMANENT FASTENINGS

Several patented kinds of special fastenings combine the advantages of permanence and flexibility. Most widely used is Moore Speediflex. This consists of an ingenious system which involves making a flexible hinge out of the carbon paper. There is a thin line of glue on both sides of the carbon; on the fastened margin. The lines are offset slightly, and

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between them is a series of diagonal "stress relieving" cuts which permit the paper parts of the form to move a short distance both horizontally and vertically in relation to each other.

Several competing fastenings are available. For the most part they are devices developed in Europe and sold in this country as attachments to Schriber and Hamilton collators.

Of all these construction options, if there is one which can be described as representing a trend in EDP, it would seem to be non-processed carbon paper crimped into the form. For years "standard" one-time carbon ran the full width of the form, and had slightly oversized marginal punching. This is still probably the most widely used. An alternative is to use carbon paper slightly narrower than the form so that the edges reach the margin, but do no extend into the line hole punching area. This kind of carbon is called non-processed. It is held either by a thin glue line, or by the innermost cuts of regular crimping. Such forms are normally "crash perforated" in the collator through all parts at once (rather than a ply at a time on the press). Although this product is said to have been originally sold as an economy item, many computer users and some equipment manufacturers feel it offers better feeding in their line printers. The tractor pins have fewer parts to find their way through. The crash perforating makes the form refold better after leaving the printer, and also helps hold the parts of the form together. In addition, the product is not premium priced, and if crimped, permits decollating without trimming off the margins.

Many other special constructions, too numerous to mention, are available. Using new materials and manufacturing techniques, computer printers can now write almost any kind of document including: continuous punched cards; pre-sealed notices in envelopes using self-contained paper; all-weather metal identification tags for appliances; pressure sensitive labels; forms incorporating both carbon and carbonless paper which can be handwritten from the bottom up after being machine written from the top down; and continuous envelopes.

FORMS HANDLING EQUIPMENT

Speedy output printers can be a curse, as well as a blessing, when viewed, for instance, by clerical personnel attempting to prepare the written continuous forms for distribution. The major operations required are bursting or cutting the forms apart, getting out the carbon paper (deleaving), separating the parts (decollating), and sometimes imprinting signatures, branch office addresses, or the like. Fortunately, equipment has been developed to mechanize these operations. Some of this equipment places the most critical demands of all on the forms. Selecting "forms handling equipment" is closely linked to the form's end use function, its construction (in particular the fastenings), and the materials.

The least-expensive equipment is a lightweight "waterfall" decollator and single-part burster. The form is separated two parts at a time, and the carbon paper wound automatically onto a spindle for easy disposal. Then each part is run through the burster where it is torn (hopefully) at the cross perforations. Such a setup can cost less than \$1000 for both machines.

Sometimes it is desirable to leave parts of the form together. In this case the carbon can be removed from the unfastened side with a deleaver, without disturbing the fastened margin. Then the form can be burst into sets with a heavy-duty, multi-part burster.

The European approach to separating forms is to cut them rather than tear them apart at the perforations. Some such equipment can cut out the perforation with two close cuts and, also, trim off the marginal punching. The resulting documents are cut clean on all four sides. These "guillotines", along with the expanded character selection now available with many line printers for upper and lower case, have greatly increased the use of computers in writing documents such as insurance policies, "personalized" form letters, and certificates. The most fully-automatic system of this type is the "document processor" sold by IBM for on-line operation with the 1403 Printer. In general, these cutters are considerably more expensive and slower than bursters.

Most decollators and deleavers can be equipped with slitting blades to trim off the pinfeed margins, and, in some cases, cut the form down the middle as well (when they are printed "two-up"). The type of crimping is worthy of special attention. With most decollators, a heavy crimp will have to be trimmed off. If both margins are fastened and have to be trimmed, the marginal holes cannot be used for binding. Another problem is paper thickness and stiffness. The newer lightweight papers—now used much more because of the lighter impact of computer printers—often create serious problems. In decollators, lightweight papers often buckle or refold improperly. In bursters, the lighter the paper, the more likely tearing or jamming will happen, especially if the perforations are not just right.

Most major producers of business forms offer a line of forms handling equipment and accessories. Some are available directly from independent manufacturers. Listed in Table 4 are sources for this equipment. It might be noted that DAL products is the U. S. distributor for the Davis burster, that Standard Register markets the FIMA cutter, and that American Permac markets the Boewe (Boehler & Weber) decollators in the U.S.A.

MORE THAN INK ON PAPER

Progressive forms manufacturers are doing more than selling ink on paper. For the most part, forms salesmen render valuable assistance in setting up new forms systems, extending in some cases into analysis of the entire paper flow. Less well known are some specialized services being offered by certain manufacturers.

As mentioned earlier, inventory control can be a major problem, especially when many different types of custom-printed forms are used. Several forms have programmed their customers' usages onto a computer, and re-ordering is automatic. Some have regional warehouses where printed forms can be held until needed. Purchase of forms is on yearly contract, with these services included.

At least one firm has attacked the problem of different, and constantly changing, laws governing wording of insurance policies in each state. Law-

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yers are retained as an "authenticating" department to keep up with court cases pending and to make sure of correct formats. These policies are printed at central plants, then distributed to regional service centers where they are control-numbered and imprinted with agents' names and addresses. The forms manufacturer exercises control over the distribution of policies for underwriters, ensures proper wording for each of the fifty states, and distributes them in lots as small as fifty forms.

One of the fastest-growing manufacturers specializes in the automotive industry. They not only design and manufacture auto dealer and repair accounting forms, they also actually perform complete accounting services. Shop orders are processed daily for customers and financial reports,

prepared from punched paper tape or adding machine tapes, are read on NCR scanners. So efficient is this service that the major Detroit manufacturers often recommend that their dealers subscribe.

These few examples of specialized services should serve to illustrate how forms manufacturers are more effectively addressing themselves to the information processing needs of their customers. Indeed, the forms industry has met the challenge of EDP and its attendant administrative problems.

FORMS DESIGN

There is no limit to the amount of information about the line printer which can be useful in design-

Table 4 • Forms Handling Equipment

MANUFACTURER OR DISTRIBUTOR	BURSTER	CUTTER	DECOLLATOR	DELEAVER	PINFEEDING DEVICE FOR TYPEWRITER
American Permac, Inc.			X		
Boehler & Weber K. G.		X	X		
F. A. Davis & Sons, Inc.	X				
Dillon-Ford & Co.	X		X		
Divi Mecana A. B.	X				
FIMA (Fabbrica Italiana Macchine Aziendali, S.p.A.)		X	X	X	
IBM Information Records Division		X			X
Moore Business Forms, Inc. (Eastern Region)	X		X	X	X
Aktiebolaget Parajett					X
Standard Register Company	X	X	X		X
Tab Products Company	X		X		
Tabulating Accessory Co.	X				
Uarco, Incorporated	X		X	X	

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ing forms for it. For instance, a subtlety such as the sequence of characters on the drum of an asynchronous printer can help. When a "preferred set" of adjacent characters are used, effective printing speed may be faster. Knowledge of which special symbols are in this preferred set might influence the forms designer's decision whether to pre-print the character on the form or let the computer print it out.

However, it cannot be said such information is always essential. Computers very seldom make all the essential information for forms design available in published form. Both the computer user and forms industry need it. Lack of such information gives rise to a great deal of expensive trial and error, and, in the end, less efficient forms often result. Due to lack of information, sometimes a "strike-off" of the variable data to be printed is made on blank paper and the form designed around it. But even this does not answer all the questions.

Here is what is considered to be essential information about a line printer in order to design adequate forms with minimum trial and error.

1. Character spacing. This is almost always given, although it is the easiest to guess anyway. All printers manufactured in the United States seem to have now standardized on ten characters per inch. The only departures are with certain accounting machines, teletypewriters, non-impact printers, the older "tab" printers, and the Bull printer mechanism now becoming common in this country.

2. Line Spacing. This should be given in lines per vertical inch, any variations possible, and if so, how much work it is to change from one to the other. Sometimes pulley changes are needed to change from six to eight lines per inch, as well as a different carriage control tape. Availability of single-double spacing under operator control should also be given.

3. Vertical format control. Is there a vertical format control unit using a paper tape as a standard feature? How many functions can be handled by the tape (number of channels)?

4. Skipping speed. This is useful in determining how much care should be taken to minimize skipping within and between forms. It is useful to know how much time is lost by skipping specific distances; in terms of number of lines skipped.

5. Number of printing positions. This normally corresponds with the number of hammers, and is sometimes called "line length." Options are normally offered here. It is good to know which is considered "standard."

6. Characters available at each position. This information should include how many, what they are, and what is the standard sequence. It should be specified whether the print element (drum, chain, train, or stick) is interchangeable to offer expanded character sets, and how this affects speed. If effective speed varies, depending upon the characters selected by the program, representative speeds should be given.

7. Absolute maximum form width. This is the width (from form edge to form edge) which can be handled with the tractors spread to their limits.

8. Maximum width to write anywhere. This is always less than the absolute maximum. It is the width which can be used that permits writing up to within a half inch of either the left edge of the form or the right edge.

9. Relate form widths to area that can be written. With line lengths commonly limited to 96, 120, 132, or sometimes 160 positions, obviously the full width of many wide forms cannot be written. Horizontal adjustment of the print unit or forms tractors can vary a great deal. A diagram should be provided showing the area that can be written with common standard-width forms, particularly with the wider ones: 14-7/8 (as many as 50% of all forms are estimated to be this width), 16-3/4 and 17-25/32. Distance of first and last not printing positions to the form margin should be shown with each of the common line lengths available with the printer, with full left adjustment and full right adjustment. The diagram for the 1443 printer, for example, would show that on a 16-3/4 inch wide form, with the 120 position model, the closest you can write to the left form edge is 1-11/16 inches (from the center of the first print position). IBM does show this. But not shown is what the distance would be with a 17-25/32 inch form, for example.

10. Horizontal and vertical vernier control. Availability of such controls often determines the practicability of designing a form with close registration. When these are not available, it is good to use a relatively "loose" layout, even though it may not be making effective use of the form area.

11. Vertical and horizontal form tension control. One of the main barriers to good "write through" is air space which develops between the parts of a form. For this reason impression quality through a wide form is not usually as good as through a narrow form. To minimize slack in the form, which affects how well the impression will carry through the form, it should be properly tensioned. Availability of two sets of tractors, and controls to adjust the distance between them, have a lot to do with what kind of write-through can be expected with varying width and thickness forms.

12. Write-through expectancy. Admittedly there are many other variables here, not to mention the lack of accurate standards for describing papers and carbons. But some effort should be made to describe the outer limits, in terms of the number of readable copies of given form thicknesses that can be expected.

STANDARDIZING TERMS

Aside from publishing these twelve items in line printer instruction manuals, it would also help if everyone could get together on terminology. Confusion, and sometimes expensive errors, result from language problems.

For example, sometimes form width is specified as the distance from tractor pin center to tractor pin center, rather than from form edge to form edge. "Skipping" is also called "slewing" or "feedout". "Positions" are also called "columns". In the form specs published by one printer manufacturer, "crimps" are termed "perforation-type fastening". All this would seem to indicate lack of

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communication between the forms industry and EDP equipment manufacturers, and among the computer manufacturers, themselves.

FORM DESIGN HINTS

Knowledge of how to design forms for line printers will probably never be boiled down to a simple check list. But as food for thought, it may be worthwhile to list a few "hints" which have been found to be useful guidelines (although there are exceptions to all of them). In general, they should help in two areas: (1) maximizing effective printout speed of the line printer itself, and (2) making machine room operations and form changing as efficient as possible.

1. Always use standard sizes. This will reduce the form cost, and ease communication with the vendor. Common standard widths are: 5-3/4, 6-1/2, 8, 8-1/2, 9-1/2, 9-7/8, 10-5/8, 11, 12, 12-27/32, 13-5/8, 14-7/8, 16-3/4, and 17-25/32. The basis for these widths, in part at least, is the widths that were required by the pinfeed platens used with the 5/32nd inch spaced "tab" equipment such as the IBM 402. Common standard lengths are 3, 3-1/3, 3-1/2, 3-2/3, 4, 5, 5-1/2, 6, 6-1/2, 7, 7-1/3, 8, 8-1/2, 10, 11, 12, 14, 17, and 22 inches. These measurements are determined by the plate cylinder circumference of the most common business forms presses.

2. Beware of form lengths greater than 11 inches, especially if any of the parts are lightweight papers. Re-folding after writing and decollating will be a problem. Forms shorter than 5 1/2 inches may also cause problems. It is often suggested that such forms be printed two to a folded set.

3. For maximum printout efficiency, make maximum use of all printing positions. If the form end-use does not permit a short, wide form, explore the possibility of printing it two-up.

4. Do not attempt to draw vertical rules between printing positions. Form registration in the printer will be too tight. Instead, draw it to split a position.

5. Do not draw horizontal rules between lines when 8 lines per inch spacing is used.

6. Pre-print a registration mark—such as a small triangle—which the operator can use against the horizontal scale when loading the form.

7. Many form problems arise from improper printer control settings, rather than faulty forms. Pre-print recommended machine control settings on the margin of the form, where it will serve as a readily accessible reference for the operator.

8. If forms are to be bound, print out the least important information on the bound side, where reading might be more difficult, rather than leaving a wide margin.

9. Consider using stock forms and printing out headings from the computer: if there is a good chance the format may be changing; if the computer operation is characterized by many short runs; if minimum setup time is desired between runs; and if easiest availability, small inventory, and low

forms cost are prime considerations.

10. Consider using custom forms if primary considerations are: attractiveness and readability, especially when forms reach the public; getting as much information as possible on a limited area of the form; making certain information stands out at a glance; and when it is almost certain that formats will not be changing for a long time.

11. Standardize on one, two, or, at most, three widths to reduce form setup time.

12. Use care in designing forms wider than the "maximum width to print anywhere", since there will be non-write areas on the form.

13. Anytime the number of parts approaches the limit for that printer and the specified materials (normally, six, seven, or eight parts), test a dummy form. The form should be the same size and of the same materials as the final printed form will be, and written, if possible, on the same printer that the real forms will be. Make sure whoever is getting the last part is satisfied with the quality of his impression.

14. Use proper tools in laying out the form. The most important are an appropriate layout chart (with printing positions indicated with a grid of light blue lines) and a good forms design ruler.

SOME USEFUL PRINTER FEATURES

Most line printers now in use are very adequate in forms handling capability. For the most part, they have the following desirable features:

- Essential form positioning controls;
- Vertical format control unit using a tape loop;
- Print unit that opens up, for easy form loading;
- Two sets of tractors.

The above features do not imply that line printers without these capabilities are less than adequate; however some printers, especially in the lower speed or cost ranges, are less than adequate for many applications.

There are some other features that are much less common which engineers have no doubt considered but ruled out for some good reason. Most of these features are available on some line printers, but no printer has all of them. Some of the recommended features, which would add little to the cost of the hardware, are summarized below.

1. A scale on the tractor slide bars. This would give the operator a point of reference for accurately and quickly aligning the tractors for different size forms.

2. Set up controls for horizontal tractor movement. This would allow the upper and lower tractors on each side to move together using a single control.

3. Program the vertical format by reading marks pre-printed on one of the form margins. This feature could either replace or work in conjunction with the vertical format.

4. Manually-adjustable set-screw to control the space between the tractor hold-down and tractor

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plate. Friction of thick forms, or forms with bumpy margins due to fastenings, often cause misfeeding. The operator should be able to adjust the gap to suit the form thickness.

5. Orient the plane between the top and bottom tractors closer to horizontal than vertical. This capability would make form loading easier.

Another area which warrants consideration is the idea of reversing the form movement. Most line printers feed the form from the front and refold it behind (the main exception being the NCR 340 series printers). The opposite would seem to offer the following advantages: the very common problem of paper improperly re-folding could be more readily monitored by the operators; boxes of forms ready to be fed into the printer would be behind, and easier to place; the written form would be more easily removed, and jobs more easily separated.

FUTURE OUTLOOKS FOR THE FORMS INDUSTRY

Trends now becoming apparent are going to pose new challenges to EDP forms technology and may, in the long run, completely re-shape the forms industry.

Character reading—first magnetic, now optical—is at last becoming significant. In a sense, the high printing demands posed by character reading has and will continue to have a healthy effect. Forms for character readers require more stringent specifications; they are specialized forms in every sense of the word. This takes them out of the domain of most commercial printers and in-house reproduction departments. MICR and OCR forms are manufactured best by business forms printers.

But this could have a backlash as well. As in the case of punched cards, card sets, and magnetic ledger cards, the close relationship of the form and proper functioning of the reading machine may serve to expand the penetration of EDP equipment manufacturers into the forms market.

The trend toward stock forms is considered significant, since this is a commodity-type item. Some observers feel that the stock portion of the industry might eventually spin off, becoming a separate industry, or be handled by paper distributors, forms dealers, or paper mills. In any case, it will leave a somewhat smaller chunk of the tremendous potential market to the leading firms, which consider the custom, high-value item to be the heart of the forms industry.

Non-impact printers have been around for a long time, and have yet to make up any significant portion of computer printout capability. But this

does not rule out breakthroughs that could change everything. In all cases, non-impact printers do not, and probably will not, use business forms in the conventional sense of the term. Specialized, coated papers, or regular paper (but imprinted and in rolls), will be used. The "form" will be printed along with the variable information by the non-impact printer.

Predicted computer sales would seem to indicate that forms will continue their spectacular growth of somewhat more than twice the rate of the GNP. However, it is also becoming apparent that new ways of using computers will result in a lot of forms being by-passed. There will be much more use of paper—but probably in rolls rather than as forms. Low cost terminals will be assuming a larger portion of printout, and these are often low-cost typewriter-like devices using rolls.

IBM's roll feed for the 1403 printer may be a predecessor of accessory equipment which, in the future, will permit feeding plain roll paper into regular line printers. It is also expected that it will only be a matter of time until there is a fast, low-cost copying process on-line with the printer to put the constant information onto the paper.

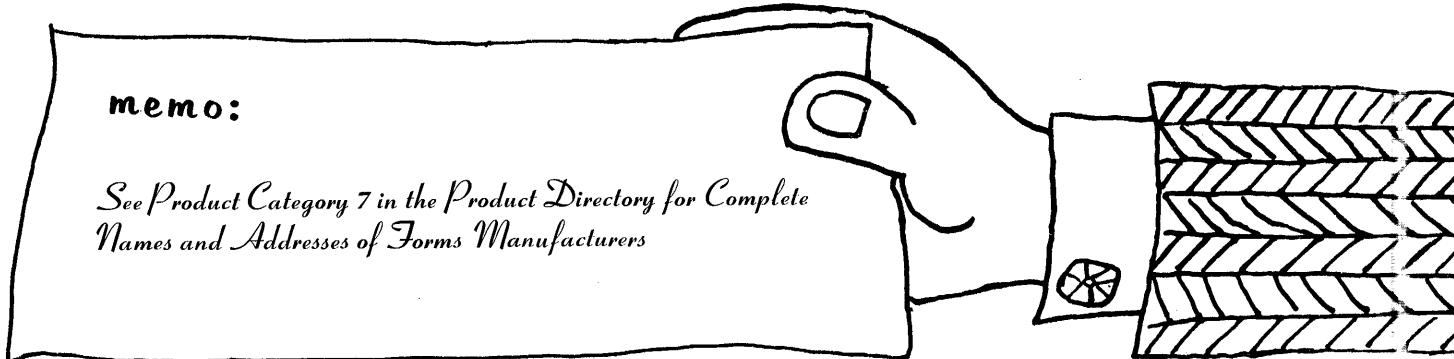
More information is remaining within the computer, in auxiliary memory devices, or is being kept in machine media, such as magnetic tape. Some government agencies, for instance, encourage firms to submit reports in the form of tapes rather than printout. There are also the non-hard copy output devices such as display and voice response.

But at the same time, new applications are appearing for conventional forms and materials. For instance, in the midst of cries that carbon paper is doomed, Xerox has introduced a low cost telecopier which employs, at the receiving end, a one-time carbon set. More and more typewriter-like devices are being equipped with pinfeed platens to handle continuous forms; for creating computer input, for typing out form letters, and for editing (where accuracy is vital, such as in legal work). When a bank converts to on-line teller terminals, a lot of unit forms are replaced by continuous forms.

In light of this, there is not much concern in the forms industry about a shrinking market. The significant trend is a closer inter-relationship between EDP and the forms industry. The forms industry is increasingly recognizing that its product is not just ink on paper, but information transmittal and control. In keeping with this thinking, it can be assumed that where information processing enters the realm of printing and the graphic arts, the forms industry will be the best qualified source of improved materials, constructions, printing, and new and imaginative services.

memo:

See Product Category 7 in the Product Directory for Complete Names and Addresses of Forms Manufacturers



EXTERNAL STORAGE SYSTEMS

A requirement of all digital systems is the storage of information in binary form. The quantity of information to be stored ranges from a few bits (status information or one character of data) in a simple system up to several Terabits ($\text{Tera} = 10^{12}$) in a large information retrieval system. The choice of a storage medium for a particular digital equipment application is part of the art of digital system design, and must be made with full understanding of the relationships among the several kinds of digital electronic memories.

Electronic memories may be grouped according to six basic storage techniques. Each technique exhibits its own characteristic speed of access, storage capacity, and cost per bit stored. These characteristics are approximated in the table below for each of the basic methods of storage.

Method	Access Times	Bits Stored	Cost Per Bit
Flip-flops & registers			
	10 ns. - 10 usec	1 - 100	\$5.00
Core Memories			
	500 ns - 50 usec	50 - 500K	\$1.00
Delay Lines			
	50 us - 50 ms	25 - 5K	\$0.50
Discs & Drums			
	10 ms - 1 sec	50K - 10G	\$0.05 - 0.001
Magnetic Tape			
	10 sec - 1 Ksec	32M - 1G	\$0.0001
Microfilm			
	1 min and up	10G and up	---

The choice of a memory (or an array of memories) will depend upon the design considerations of each particular system. For example, a system designed for sequential batch processing will impose constraints upon the choice of a memory which are different from the constraints of an on-line random-access system. It is, however, possible to make some empirical generalizations about the cost/performance trade-offs in the choice of a memory, and the designer finds that the less stringent his access time requirement and the more use he can make of a larger-capacity storage, the less will be his per-bit cost of storage.

For a given system, the storage capacity and access time requirements will be used to determine the memory or combination of memories chosen to create a least-cost solution.

Rotating Memories

Memory requirements in the range of 10^5 to 10^9 bits, with access times of 0.01–1.0 second, are usually solved by rotating memories using a magnetic surface as the storage medium. In these devices, a thin magnetic coating is applied to a drum,

disc, tape, or card, and the magnetic surface, thus created, is rotated past magnetic heads used to read or write on the surface. Variations in implementation of storage devices using this technique are many. For the purposes of classification, we shall make divisions by the functional parameters of access time and storage capacity, rather than consider the storage mechanism (disc, drum, tape), and we will consider only those storage systems with access times of less than one second. Within this class are the following two major categories.

- Devices having one or more fixed-position head(s) for each track on the magnetic surface.
- Devices having a movable mechanism which causes the head(s) to be positioned over any of a group of tracks wherein the number of heads is less than the number of tracks.

In general, we shall see that the second category will be slower in access time than the first, due to the time required to move the head-positioning mechanism. We shall also find that for large storage capacity, devices in the second category are less expensive due to the fewer number of heads required.

PRIMARY OPERATIONAL CHARACTERISTICS

Within these categories, there are a number of operational characteristics which are of importance in selecting a memory device. Primary among these are the following.

- Storage capacity of the device.
- Removable- or fixed-medium. In a fixed-medium device, the memory element (the magnetic-surfaced component) is built in. In a removable-medium device, the memory element can be removed and stored, with another memory element replacing it in the device. Thus a fixed-medium device can be used only up to the limit of its storage capacity, while a removable-medium device can utilize different—but full-capacity—storage elements for tasks requiring the contents of only one element. The total number of bits “on-line” is not altered by removability, but the total number of bits to which the device may have access is made, in effect, unlimited, just as a magnetic tape handler can utilize any recorded tape.
- Storage capacity of a data cylinder. In accessing movable-head devices, each of the n heads has access to a group of tracks, and all are moved simultaneously. After positioning, there are n heads ready to read or write from or onto any of n tracks, despite the fact that access to only one of the tracks was desired. If the next access

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is to one of the n tracks currently under a head, then no time need be taken to move the positioning device, therefore access time is reduced. Also, use may be made of the fact that n tracks are in operating position by conducting parallel operations using more than one track at a time. The n tracks which may be accessed without moving the heads constitute a data cylinder, and the number of cylinders making up the total storage equals the number of tracks to which any one head can be positioned. In a fixed-head device, there is only one cylinder, and it consists of the total storage capacity.

- Access time to any location. The average time to reach a particular position on a particular track is the time to position the heads (if applicable) plus one-half of the rotation time of the device (the "half-latency time").
- Transfer rate. The rate at which data is written onto or read from the device.

OTHER CHARACTERISTICS

- Overlap capability. Are there multiple head positioners so that positioning for the next access can be done simultaneously with the present read/write? Can read/write be done with more than one head at a time?
- Storage medium. Magnetically-coated disc, drum, card, or tape.
- Number of recording surfaces.
- Number of tracks per recording surface; total number of tracks.
- Number of bits per track.
- Track density or spacing.
- Bit recording density.
- Data recording and clocking method.

DEVICE CONFIGURATIONS

The physical configurations of the various types of rotating memories are described below in order to relate them to the above terminology.

- Magnetic Drum. The memory element is a metal cylinder, magnetically coated over its curved surface, and rotating about the axis through its circular ends. In the fixed-head version, the heads are fixed in the drum housing, always sweeping the same circular track, and a head exists for each track. In the movable-head version, a head exists for each group of m tracks, and all heads are moved within their groups by a mechanical positioner. Drum memories are fixed-medium.

- Magnetic Disc File. The memory element is one or a number of metal discs, magnetically coated on both flat sides, and rotating about the axis perpendicular to the centers of its flat sides. If there are more than one disc, they are stacked on this axis, and rotate on a common shaft. In the fixed-head version, fixed heads are

mounted so as to cover all tracks on all disc surfaces. Several movable-head versions are possible: one has only one pair of heads which can move to any position on any disc; another has one or more heads per disc surface, all moving parallel to the recording surface; other variations also have been implemented.

A data cylinder in the drum or disc memory consists of the contents of all the tracks under heads at any position of the positioning mechanism. Latency time for both devices is the rotation period of the disc or drum. Disc files can be either fixed- or removable-media.

- Magnetic Card Memory. The memory element is a thin (5-8 mils), flexible magnetically-coated Mylar card. Many of these cards are stored in a cartridge. For a given access, one card is selected from the stack and wrapped around a drum, which has fixed heads for read/write on the card while it is on the drum. To access a location not on that card, the card is returned to the stack, and another card selected. This device can be considered to be a drum with a changeable surface. Magnetic card memories are usually removable-media, since the card stack is easily changed. A cylinder is one card, and the latency time is the rotation period of the drum.

- Magnetic Tape Loop Memory. The memory element is an endless loop of magnetic tape, driven past the read/write station. Many loops constitute a cartridge, and there are one or more read/write heads per loop, positionable across the tape. The cartridge is usually removable. A cylinder consists of the contents of all the tracks under heads at any position of the head positioner. Latency time is the rotation period of the tape loop. (There are also single-loop magnetic tape memories which, strictly speaking, are rotating memories; however, their access times are orders of magnitude greater than the memories in this class, due to the much greater length of the tape loop; therefore, they are classed as magnetic tape storage systems rather than rotating memories.)

- Optical rotating memories. A variety of optical memories using photographic film discs, cards, or chips have been used over the past ten years. These are read-only memories, since the information on the film cannot be changed; none has been actively marketed in a production version, and they are therefore not included in this survey.

A compilation of the characteristics of available rotating memories is presented on the following pages. These memories are separated into two groups; those having a fixed head per track, and those having positionable heads; within each group, the memories are listed in increasing order of total storage capacity.

EXTERNAL STORAGE SYSTEMS

Head-Per-Track Devices

MODELS LISTED IN ASCENDING ORDER BY CAPACITY

MANUFACTURER	MODEL	CAPACITY (Million Bits)	ACCESS TIME (Milliseconds)	STORAGE ELEMENT	NO. OF TRACKS	DENSITY (Bits/inch)	APPROX. PRICE (\$ 000)
WESTERN MAGNETICS	602-5-2	0.025	8.3	Drum	3	530	3
VERMONT RESEARCH	52	0.20	8.3	Drum	—	—	—
LIBRASCOPE	L321-8	0.34	8.3	Disc	45	500	2.5
MAGNEHEAD, G.I.	71-64	0.50	8.5	Disc	64	532	3.5
WESTERN MAGNETICS	402-55	0.54	2.5	Drum	162	192	10.9
LIBRASCOPE	L322-8	0.67	8.3	Disc	90	500	—
MAGNEHEAD, G.I.	71-128	0.70	8.5	Disc	128	500	4.5
MAGNEHEAD, G.I.	91-64	0.70	8.5	Disc	64	533	4.5
DATA DISC	F.75	0.80	16.7	Disc	8	3330	5.9
MAGNEHEAD, G.I.	111-64	1.0	8.5	Disc	64	533	5.5
MAGNEHEAD, G.I.	91-128	1.1	8.5	Disc	128	533	5.5
BRYANT	5064	1.1	2.5	Drum	90	800	—
LIBRASCOPE	L-110-8	1.2	8.3	Disc	72	1000	4.3
MAGNEHEAD, G.I.	131-64	1.2	8.5	Disc	64	533	6.5
MAGNEHEAD, G.I.	72-256	1.3	8.5	2 discs	256	500	6.5
LIBRASCOPE	L-207-4	1.3	3.3	Disc	132	1000	15.0
MAGNEHEAD, G.I.	111-128	1.6	8.5	Disc	128	533	6.5
DATA DISC	F1.5	1.6	16.7	Disc	16	3330	6.9
BRYANT	75064	1.7	5.0	Drum	90	800	—
WESTERN MAGNETICS	602-12	1.9	8.3	Drum	128	400	9.5
MAGNEHEAD, G.I.	131-128	2.0	8.5	Disc	128	548	7.5
BRYANT	5128	2.0	2.5	Drum	156	800	—
MAGNEHEAD, G.I.	92-256	2.3	8.5	2 discs	256	533	7.5
LIBRASCOPE	L-210-8	2.4	8.3	Disc	144	1000	6.0
VERMONT RESEARCH	104-S	2.6	3.7	Drum	128	—	—
BRYANT	75128	2.9	6.7	Drum	156	800	—
SDS	9366/67	3.1	17.5	Discs	—	—	23.1
MAGNEHEAD G.I.	112-256	3.1	8.5	2 discs	256	533	8.5
DATA DISC	F3	3.2	16.9	Disc	32	3330	9.7
BRYANT	5256	3.6	3.8	Drum	288	800	—
DIGITAL DEV.	7301-1	3.8	8.5	Disc	128	1000	—
VERMONT RESEARCH	154	3.8	8.3	Drum	128	—	—
BRYANT	10128	3.9	6.7	Drum	156	800	—
MAGNEHEAD, G.I.	132-256	4.1	8.5	2 discs	256	548	9.5
APPLIED MAGNETICS	MDM-12-1	4.2	17.0	Disc	128	1000	—
UNIVAC	FH330	4.7	8.5	Drum	256	—	—
VERMONT RESEARCH	108	5.1	8.3	Drum	256	—	—
BRYANT	75256	5.4	6.7	Drum	288	800	—
SDS	RAD7202	6.0	17.0	Disc	128	—	18.0
LIBRASCOPE	L116	6.0	8.3	Disc	128	1500	15.5
RCA	70/565-12	6.3	8.6	Drum	256	800	—
DATA DISC	F6	6.4	16.7	Disc	64	3330	12.6
IBM	7320	6.6	8.6	Drum	400	—	—
BRYANT	10256	7.2	8.4	Drum	288	800	—
VERMONT RESEARCH	158	7.7	8.3	Drum	256	—	—
DIGITAL DEV.	7301-2	7.7	8.5	2 discs	256	1000	—

EXTERNAL STORAGE SYSTEMS
Head-Per-Track Devices (Cont'd.)

Models Listed in Ascending Order by Capacity							
MANUFACTURER	MODEL	CAPACITY (million bits)	ACCESS TIME (milliseconds)	STORAGE ELEMENT	NO. OF TRACKS	DENSITY (bits/inch)	APPROX. PRICE (\$000)
UNIVAC	FH432	7.9	4.3	Drum	432	—	—
HUGHES	Airborne	8.0	8.7	Drum	170	1000	—
MAGNEHEAD, G.I.	134-512	8.2	8.5	4 discs	512	548	13.5
APPLIED MAGNETICS	MDM-12-2	8.5	17.0	2 discs	256	1000	—
VERMONT RESEARCH	116	10.2	8.3	Drum	512	—	—
BRYANT	10384	11.0	8.4	Drum	440	800	—
SDS	RAD7203	12.0	17.0	Disc	256	—	27.0
LIBRASCOPE	L216	12.0	8.3	Disc	256	1500	19.3
VERMONT RESEARCH	1116	12.5	8.5	Drum	512	800	20.0
RCA	70/565-13	12.5	8.6	Drum	512	800	—
SDS	9366/67	12.6	17.5	Disc	—	—	47.2
BRYANT	185256	13.4	16.7	Drum	288	800	—
BRYANT	10512	14.5	8.4	Drum	576	800	—
VERMONT RESEARCH	166	15.4	8.3	Drum	512	—	—
DIGITAL DEV.	7302-4	15.4	8.5	4 discs	512	1000	—
HONEYWELL EDP	270A1	15.7	26.5	Drum	512	560	—
LIBRASCOPE	L124	16.4	16.7	Disc	256	1500	19.5
APPLIED MAGNETICS	MDM-12-4	16.9	17.0	4 discs	512	1000	24.0
LIBRASCOPE	L316	18.0	8.3	Disc	384	1500	29.0
MAGNEHEAD, G.I.	S20M512	20.0	8.5	Drum	512	1200	24.0
MAGNEHEAD, G.I.	D5000	20	8.5	Drum	—	1200	35
VERMONT RESEARCH	216A	20.0	17.0	Drum	512	700	25.0
BRYANT	185384	20.4	16.7	Drum	440	800	—
VERMONT RESEARCH	132	20.5	8.3	Drum	1024	—	—
SDS	RAD7204	24.0	17.0	Disc	512	—	35.0
LIBRASCOPE	L416	24.1	8.3	Disc	512	1500	32.8
BRYANT	185512	26.8	16.7	Drum	576	800	—
UNIVAC	FH880	28.3	8.5	Drum	768	—	—
DIGITAL DEV.	7303-8	30.7	8.5	8 discs	1024	1000	—
VERMONT RESEARCH	182	30.7	8.3	Drum	1024	—	—
IBM	2303	31.3	8.6	Drum	800	—	—
HONEYWELL EDP	270A2	31.5	26.5	Drum	512	560	—
LIBRASCOPE	L224	32.7	16.7	Disc	512	1500	30.3
IBM	2301	32.7	8.6	Drum	800	—	—
SDS	RAD7212	33.6	17.5	Disc	512	—	40.0
VERMONT RESEARCH	232	41.0	8.3	Drum	1024	—	—
HONEYWELL EDP	270A3	47.2	26.5	Drum	512	560	—
BRYANT	1851024	47.6	16.7	Drum	1024	800	—
LIBRASCOPE	L324	49.2	16.7	Disc	768	1500	45.3
MAGNEHEAD, G.I.	560M1024	60.0	17.0	Drum	1024	1200	40.0
BURROUGHS	BC475	60.0	20.0	4 discs	1200	1100	35.0
LIBRASCOPE	L424	65.5	16.7	Disc	1024	1500	56.0
LIBRASCOPE	L238	100.4	33.3	Disc	1024	1300	62.0
VERMONT RESEARCH	264B	102	17.3	Drum	2048	—	—
BURROUGHS	BC475-1A	102.0	30.0	4 discs	1200	1550	35.0
BURROUGHS	BC475-1B	120.0	40.0	4 discs	1200	2275	35.0
BURROUGHS	BC475-1C	200.0	40.0	4 discs	1200	3500	35.0
LIBRASCOPE	L438	200.7	33.3	Disc	2048	1300	107.0

EXTERNAL STORAGE SYSTEMS

Positionable-Head Devices

Models Listed in Ascending Order by Capacity												
MANUFACTURER	MODEL	CAPACITY (million bits)	AVERAGE POSITIONING TIME (milliseconds)	HALF-LATENCY TIME (milliseconds)	STORAGE ELEMENT	NO. OF CYLINDERS	TRACKS PER CYLINDER	DENSITY (bits/inch)	OVERLAP AVAILABLE?	REMOVABLE OR FIXED	APPROX. PRICE (\$000)	
OPTIMIZED DEVICES	MD-9	0.036	25	25	Disc	9	1	200	No	R		
DATA DISC	M6	6.5	315	25	Disc	130	1	3000	No	R	7.4	
IBM	1311	12.0	150	21	Discs	100	10	—		R	—	
CONTROL DATA	852	14.0	70	20	5 discs	100	10	988	Yes	R	—	
CONTROL DATA	853	24.6	70	13	5 discs	100	10	1105	Yes	R	—	
HONEYWELL EDP	258	27.5	85	13	5 discs	100	10	1105	Yes	R	21.9	
NCR (CRAM)	EM-H1	33.6	235	—	256 cards	256	56	260	No	R	—	
NCR (CRAM)	EM-H2	48.0	235	—	128 cards	128	56	700	No	R	—	
CONTROL DATA	854	49.2	70	13	5 discs	200	10	1105	Yes	R	—	
POTTER INSTR. (RAM)	TLM-4550	50.2	71	25	16 loops	28	64	1020	No	R	19.0	
HONEYWELL EDP	256/259/A	55.0	85	13	5 discs	203	10	1105	Yes	R	31.0	
RCA	70/564	60.0	85	13	5 discs	200	10	1100	No	R	25.5	
IBM	2311	60.0	75	13	6 discs	200	10			R	—	
APPLIED MAGNETICS	MCM-2	90.0	90	30	64 cards	64	128	800	No	R	30.0	
NCR (CRAM)	EM-H3	96.0		—	256 cards	256	56	700	No	R	—	
GENERAL ELECTRIC	DSU204	141	199	—	Discs	—	—	—	—	—	—	
IBM	1301	168	165	17	Discs	250	40	—	—	F	—	
BRYANT	PhD170	170	38	17	Drum	64	43	1000	Yes	F	—	
IBM	2316	200	75	13	11 discs	200	18			R	—	
DATA PRODUCTS	5022/5/6	225	205	25	16 discs	64	128	600	Yes	F	—	
NCR (CRAM)	353-5	496	166	—	384 cards	384	—	—	No	R	—	
IBM	1302	702	165	17	Discs	500	40	—	—	F	—	
DATA PRODUCTS	5045	765	115	25	32 discs	64	256	1000	Yes	F	—	
IBM	2302	896	165	17	25 discs	500	45	—	Yes	F	—	
HONEYWELL EDP	261	900	70	26	36 discs	256	64	—	No	F	—	
HONEYWELL EDP	262	1800	70	26	72 discs	256	128	—	No	F	—	
IBM	2321	3200	450	25	2000 strips	2000	100	—	No	R	—	
BRYANT	4000	3800	92	25	26 discs	256	300	800	Yes	F	—	
UNIVAC	Fastrand 1	3892	92	17	Drum	96	64	1000	No	F	—	
RCA	70/568	4300	447	30	2048 cards	2048	128	1400	Yes	R	—	
UNIVAC	Fastrand 2	7784	92	17	Drum	192	64	1000	No	F	—	

DIGITAL MAGNETIC TAPE SYSTEMS

Digital magnetic tape holds a unique place among data storage techniques. It has become the traditional mass storage medium for electronic data processors, comparable to the role of punched cards for electromechanical processors. And, like punched cards, it has proved adaptable to performing certain logical as well as storage functions. As a result, virtually every data processing installation of any size incorporates magnetic tape units. As a further result, there are now many manufacturers of magnetic tape units. Most of them produce

available have become fairly well standardized at certain increments, so have the data transfer rates.

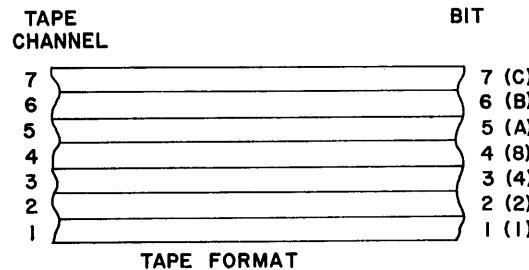
Tape units with data transfer rates of 120 or 96 KC (thousands of characters per second) using standard NRZ or NRZI recording techniques are classified here as high-speed units.

Medium-speed units are defined as those capable of data transfer rates from 50 to 90 KC. These units are versatile machines capable of operating with a wide variety of medium-(and sometimes large-) scale computers. They are also able to meet the

TABLE 1 • The IBM BCD (7-Bit) Code (Parity Bit Not Shown)

BIT POSITIONS	6	0	0	1	1
	5	0	1	0	1
4	3	2	1		
0	0	0	0	BLANK	-
0	0	0	1	/	J A
0	0	1	0	2	S K B
0	0	1	1	3	T L C
0	1	0	0	4	U M D
0	1	0	1	5	V N E
0	1	1	0	6	W O F
0	1	1	1	7	X P G
1	0	0	0	8	Y Q H
1	0	0	1	9	Z R I
1	0	1	0	0	# ! ?
1	0	1	1	# ,	\$.
1	1	0	0	@ %	* □
1	1	0	1	=	
1	1	1	0		
1	1	1	1	✓	" △ ≡

- ✓ TAPE MARK
- ‡ GROUP MARK
- " SEGMENT MARK
- △ MODE CHANGE
- ‡ RECORD MARK
- = WORD SEPARATOR



very good equipment, and the potential user is, to a certain extent, able to select a unit according to his special requirements, rather than adjusting his requirements to the hardware available.

Data transfer rate is a major criterion for any magnetic tape user. If the tape unit is to be used solely for computer input-output, the user simply selects a unit with a transfer rate which is compatible with that of the computer—normally, a unit marketed by the computer manufacturer. However, an increasing number of users require magnetic tape units for specialized systems in which the tape unit is essentially an interface between a computer and various data acquisition or transmission devices. Such applications range from meteorological to geological, wind tunnels to destructive testing, telemetry-source-unspecified to biomedical research. Typically, data from one or many sensors is presented in digital form to the tape unit, which must then present it to a specific computer for processing. The tape unit is therefore required to receive data at one rate and reproduce it at another, and usually in a different format. The device which provides or requires data at the highest rate determines which tape unit must be used.

The data transfer rate of any tape unit is simply the packing density (in linear bits per inch) multiplied by the tape read/write speed (in inches per second). Since both the packing densities and speeds

data recording and storage requirements of almost all of the more common off-line applications. Some of these units are also capable of higher transfer rates by using special recording techniques (e.g., phase modulation) or special formats.

Low-speed units generally operate under 50 KC. Note that "low-speed" is strictly a relative term, and by no means implies low performance or poor design. Many low-speed units are suitable for use with small- and medium-scale computers and can offer a considerable saving in costs. For off-line applications which do not directly involve a computer (data storage, conversion, transmission), low-speed units are often not only adequate but ideal.

After data transfer rates, the magnetic tape user is likely to be most interested in selecting the data coding and format which are compatible with his requirement. Tables 1 through 3 summarize the major magnetic tape languages. Table 1 is IBM's long-established 7-channel BCD code, which is used with the popular 1401 computer among others. Table 2 illustrates the Extended BCD Interchange Code (EBCDIC) used in both the RCA Spectra 70 and the IBM System/360. Note that the EBCDIC tape format rearranges the code bits to bring the most variable values towards the center. Table 3 gives the new American Standard Code for Information Interchange (ASCII), recently revised to com-

EQUIPMENT CHARACTERISTICS REVIEW

plete the bit assignments, together with a proposed ASCII format for 9-channel magnetic tape.

For the user with complex interface requirements, Table 4 compares the major recording techniques used with digital magnetic tape.

INCREMENTAL MAGNETIC TAPE UNITS

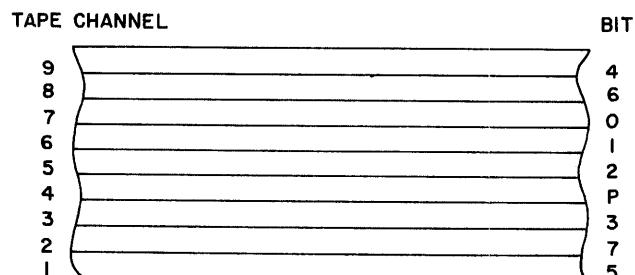
Incremental magnetic tape units differ from other digital types in that the tape is started and stopped for each character. This technique finds its major advantage in applications where input data is received at a highly variable rate (e.g., manually-operated keyboards, telemetry systems) but must be recorded at regular spacing and in a standardized format for computer input, off-line processing, or further transmission. Incremental tape units are

usability, and—if necessary—high-speed computer entry.

All incremental tape units are primarily stepping recorders. Some also offer stepping playback of the data. A further refinement in some units permits synchronous as well as asynchronous operation (record, playback, or both). Finally, some incremental units offer direct computer compatibility in the recording format used. These features are available in a variety of combinations in the incremental tape units currently on the market, and the potential user must carefully evaluate his own requirements to determine exactly what he needs. For example, if data accuracy (a "clean tape") is a major criterion, it may be advisable to select a unit with both incremental and constant-speed playback capabilities, so that after data has been recorded, the tape can be read back at high

TABLE 2 • The EBCDIC Code

BIT POSITIONS	8	0	0	0	0	0	0	0	I	I	I	I	I	I	I	I
	7	0	0	0	0	I	I	I	0	0	0	0	I	I	I	I
	6	0	0	I	I	0	0	I	0	0	I	I	0	0	I	I
	5	0	I	0	I	0	I	0	0	I	0	I	0	I	0	I
4 3 2 1																
0 0 0 0	NUL	PF				LC			HT				DEL			
0 0 0 1	h d	b	f	a	i	e	c	g								
0 0 1 0	BLANK	←	?	+	.	(.	‡								
0 0 1 1	> H D	B	F	A	I	E	C	G								
0 1 0 0	BYP		EOB	LF				PRE								
0 1 0 1	y u	s	w	z	v	t	x									
0 1 1 0	—	%	—	/	,	~	,	±								
0 1 1 1	‡ Y U	S	W	Z	V	T	X									
1 0 0 0	RES		BS	NL			IDL									
1 0 0 1	q m	k	o	j	r	n	p									
1 0 1 0	ampersand	*	!	;)	\$	\$								
1 0 1 1	< Q M	K	O	J	R	N	L	P								
1 1 0 0	PN		UC		RS		EOT									
1 1 0 1																
1 1 1 0	@	:	=	"	/	#	✓									
1 1 1 1	0 8 4	2	6	1 9 5	3	7										



often used in conjunction with Teletype, DataPhone, or similar devices as communications rate changers; data received on one line at one rate is recorded for transmission on another line at another rate, with serial/parallel conversion if required.

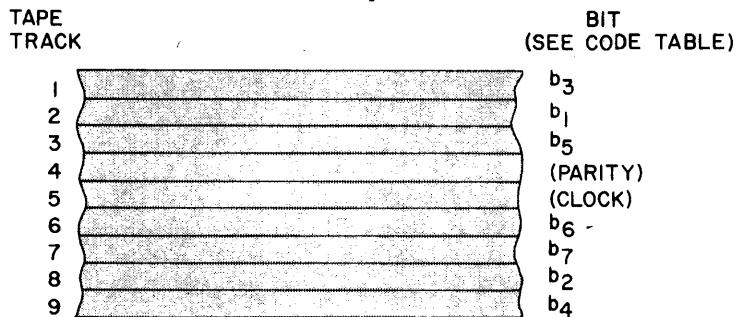
Functionally, incremental magnetic tape bridges the gap between paper tape and synchronous magnetic tape. Paper tape is still preferable for many low-speed applications, but price rises sharply as speed requirements increase, and problems tend to rise almost as sharply. Incremental magnetic tape offers not only higher speeds with attendant increases in reliability and economy, but also advantages in high-packing densities, re-

speed until an error is detected; then stopped, backed up, and read character-by-character until the fault is pin-pointed for correction. On the other hand, a simple, inexpensive unit capable only of incremental recording may be suitable for many data logging operations. However, if the unit is intended to produce tapes for input to an IBM or similar computer, the time required to insert the 3/4-inch gap between data records may be crucial, in that any data received during this time period must either be stored or lost.

The user should also be aware of the difficulties involved in asynchronous playback—difficulties which seriously degraded the performance of some first-

EQUIPMENT CHARACTERISTICS REVIEW

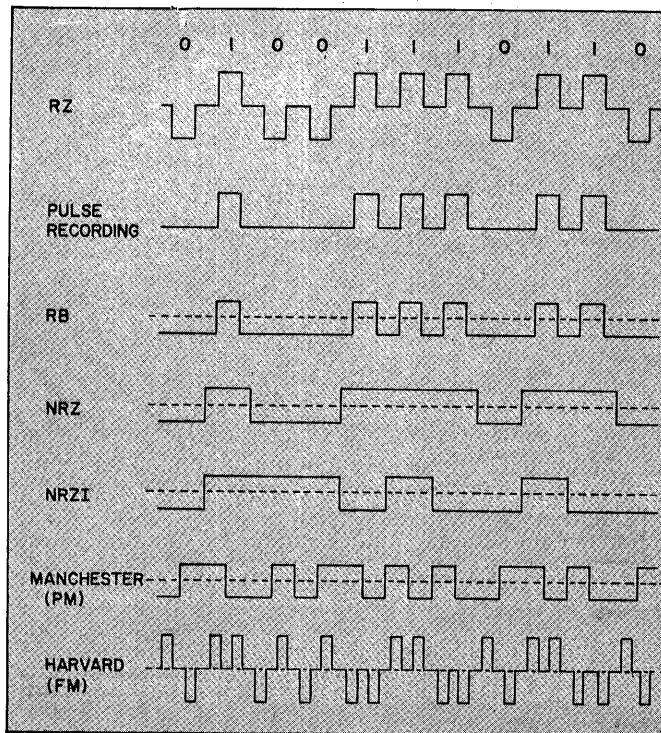
TABLE 3 • The Recently-Revised ASCII Code



RECOMMENDED ASCII TAPE FORMAT (1966)

b ₇ b ₆ b ₅				Column →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
Bits ↓				Row ↓	b ₄	b ₃	b ₂	b ₁				
0	0	0	0	0	NUL	DLE	SP	0	`	P	@	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	\$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	8	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(8	H	X	h	x
1	0	0	1	9	HT	EM)	9	I	Y	i	y
1	0	1	0	10	LF	SS	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[k	{
1	1	0	0	12	FF	FS	,	<	L	~	l	`
1	1	0	1	13	CR	GS	-	=	M]	m	}
1	1	1	0	14	SO	RS	•	>	N	^	n	l
1	1	1	1	15	SI	US	/	?	O	—	o	DEL

Table 4 • Recording Techniques



generation incremental magnetic tape units, and which may still cause problems from time to time. Reading data from magnetic tape requires the tape to be moving past the read head at a controlled speed and distance, so that a predictable number of magnetic flux lines will occur through the head coil to produce the desired signal output. When the tape must be started, brought up to reading speed, then stopped again for each individual character position, the design problems become challenging. Naturally, this problem arises only in the case of character-by-character reading. No major difficulties are involved in asynchronously recording data for constant-speed playback.

Most incremental tape units offer a high degree of reliability within the parameters which they were designed to meet, but specifications should be checked in some detail. The Product Summary Chart presents the major characteristics of units on the market, but the potential user is advised to obtain from the manufacturer not only detailed specifications, but also a sample tape for use in checking compatibility.

DIGITAL MAGNETIC TAPE EQUIPMENT (7 TO 90KC)

MANUFACTURER	MODEL	MAX. R/W SPEED (IPS)	MAX. PACKING DENSITY (BPI)	START/STOP TIMES (MS)	APPROX. PRICE	COMMENTS
AMPEX	TM-7/7211	45	800	10/10	—	
	TM-9	75	800	—	6-13K	
	TM-13	75	800	6/6	14-20K	
BURROUGHS	BC-422	120	556	3/3	17.9K	
CEC	DR-3000	75	800	4/3	8-11.5K	
CONTROL DATA	604	75	800	3/3	26K	
	606	150	556	3/2	36K	
	601	37.5	556	3/3	11K	
	603	75	556	3/3	24K	
DATAMEC	D2020	45	800	5/1.5	5-15K	
	D3030	75	800	5/2	7-16K	
DIGITAL EQUIP.	TU55	97	350	200/150	—	
HONEYWELL EDP	204A	120	533	3.5/3.5	20-43K	Complete series of models
	204B	120	556	3/3	28.3K	Complete series of models
NCR	EM-F1	60	556	7.6/7	6.5-9K	Transport only
POTTER INSTR.	MT-24	36	800	5/2	3.44K	
	MT-36	50	800	5/2	3.54K	
	MT-75	75	800	3/2	4K	
	8C-1060	112.5	800	5/3	—	
S-I ELECTRONICS	DT-03	37.5	200	5/5	11.5K	

DIGITAL MAGNETIC TAPE EQUIPMENT (96 TO 120KC)

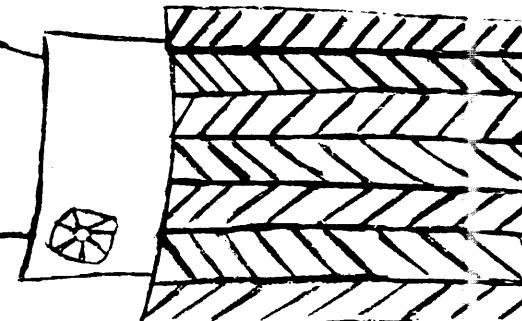
MANUFACTURER	MODEL	MAX. R/W SPEED (IPS)	PACKING DENSITY (BPI)	START/STOP TIME (MS)	COMMENTS
AMPEX	TM-11/11200	120	200,556,800	3.8/3.8	Modular; single capstan
	TM-12/12700	150	200,556,800	3/3	Modular; single capstan
CONTROL DATA	607	150	200,556,800	2.75/1.75	
	626	150	800	2.5/2.25	
HONEYWELL EDP	204B-9	120	556,800	—	
MIDWESTERN INSTR.	M4000-2	120	200,556,800	3.5/3	
	M4000-1	150	200,556,800	3.5/3	
R. M. PARSONS	DR1200	120	200,556,800	4/4	Portable
POTTER INSTR.	SC-1065	120	200,556,800	4/4	Single capstan
	MT-120	120	800	3/1.5	Modular
	SC-1080	150	200,556,800	3/3	Single capstan
	SC-1150	150	200,556,800	3/3	Single capstan; militarized
	FT151/152	150	200,556,800	50/100	DC operation
	M90611-2	150	200,556,800	3/2	Modular

INCREMENTAL MAGNETIC TAPE EQUIPMENT

MANUFACTURER	MODEL	MAX. R/W SPEEDS (char./sec.)		PACKING DENSITY (BPI)	STORAGE	APPROX. PRICE	COMMENTS
		ASYNC. R/W	SYNC. R/W				
CUBIC CORP.	TH-3700	-/300	6000/-	200	—	35K	Militarized
DARTEX	101	75/75	1200/1200	556	Reels	2-3K	
DIGI-DATA	DSR 1420	-/200	1500/1500	200, 556	Coax reels	3.45K	
	DSR 1430	-/300	1500/1500	200, 556	Coax reels	3.85K	
	DSR 1440	-/400	1500/1500	200, 556	Coax reels	4.25K	
	DSR 1450	-/500	1500/1500	200, 556	Coax reels	5.17K	
HONEYWELL EDP	6200	100	200	200	Reels	—	Write-only
KENNEDY CO.	DS-300	500	—	200	Cartridge	2.7-4K	Write-only; militarized
	DS-370	300	—	200, 556	Reels	5.5-7K	
	DS-370IR	150/300	—	200	Reels	8.5K	Militarized
	DSP-340	50	—	200	Cartridge	2.32K	Write-only; portable
	1400	-/200	—	200, 556	Reels	3-6.5K	DC operation optional
	M-201	65/65	—	200	Cartridge	—	
R. M. PARSONS	AIR-940	400	—	200, 556	Coax reels	21-22K	Write-only; militarized
	DIR-940	600	—	556	Coax reels	—	Write-only; militarized
PRECISION INSTR.	PI-1107	300/300	600/600	200, 556	Reels	10K	
	PI-1167	200	500	200	Reels	3.65K	Write-only
	PI-1177	200	500	200	Reels	5.8K	Write-only; portable
POTTER INSTR.	MT-SR	500/500	—	200	Reels	8-13K	
	MT-SW	300	—	200, 556	Reels	4-5.5K	Write-only
TRAK	DS-2	333/333	333/333	83.3	Bin	3.3K	Bi-directional

memo:

*See Product Category 10
in the Product Directory
for names and addresses of
Digital Magnetic Tape
Systems Manufacturers.*



COMPUTER PRINTERS

Printers exist basically to perform one of two functions. The first function, data monitoring, is to provide a permanent, continued, human-readable record of the values indicated by an instrument or device, over a period of time, without human attention. The second function is high-speed data accumulation—to record data emanating from a high-speed device at a rate much higher than humans can accept it. Most printer applications manifest aspects of both of these functions to some degree.

A data logging printer exists primarily to perform the monitoring function, but the rate at which readings are taken may be at a high-speed because the printer is capable of recording data at much higher speed than a human.

A computer-output printer performs primarily the high-speed data accumulation function, but it has a monitoring implication in most applications.

A communications-line printer has approximately equal amounts of both functions.

Perhaps the most general distinction which can be made is that data logging printers record data which is transient and will not be repeated; while high-speed data accumulation printers record data which is the result of some data processing operation. However, finely-drawn definition is unnecessary since printers are better classified by their capabilities in the areas of speed, numbers of columns, and character repertoire.

Corresponding to the above classification, the three common application areas where digital printers are found are computers, communications, and data logging. This is not meant to be used as a strict rule separating three completely different types of printers, but to be used as a guideline, since printers designed for one application are often found in other applications.

- Computer printers are classified as high-speed, wide-format printers which accept data in a character-serial format. These printers are usually driven from a computer and high speeds are required to maintain system throughputs. Page widths of up to 160 columns are used to facilitate the organization and tabulation of complex and massive data, but narrow page widths of 80 and 40 columns are sometimes used when the organization of the data is more simplified. A character-serial line buffer is usually used with this type of printer, since the computer is feeding data character serial through its I/O bus, at a rate incompatible with the printer.

- Communications printers are generally bit-serial entry since they must interface to a communication channel. Page widths vary somewhat on these printers depending upon the organizational requirements of the printout, but for the most part the standard width is 80 columns. Speeds of no more than

10 characters per second are required when human communications are concerned, such as in a teletypewriter environment. However, if a computer is feeding data over telephone lines, printing speeds of 300 or more characters per second are usually required.

Data logging printers are normally used to record events collected from data acquisition systems. These are usually numeric printers printing at a page width no wider than 20 columns. Speeds are determined by the sampling rate of the system, or the conversion rate of the analog-to-digital converter in the system, and seldom exceed 40 lines per second. Data entry is usually bit-parallel for the entire line, as produced by the A-D converter and associated data identifying sources such as a clock or channel number.

PRINTING TECHNIQUES

Generally speaking, printing techniques consist of impact printing and non-impact printing; impact techniques are used in the majority of digital printers. An impact printer must have the ability of selectively presenting a character type face from a character set, or font, to a print position on the paper. This can be done a character-at-a-time or a line-at-a-time; however, the manner in which the character set is made selective determines the speed and printing technique.

Selection of a character within a set can be accomplished in the following ways.

1. Individual character-type bars which can be moved to a single print position on command—such as a typewriter.
2. Prepositioned font bar which contains the entire character set and is selectively movable so the desired character can be brought to the print position. This is frequently referred to as “tab” printing.
3. Continuously-moving font bar which presents all the characters in the set to each print position so that a properly-timed firing of a hammer will print the selected character. This is called “on-the-fly” printing.

There are variations on the three techniques; however, they all use the same principle and are confined to the same speed.

The slowest of these techniques is the first, which is limited to 10 characters per second or less, as it is basically a serial device allowing only one type bar to be operated at a time. This technique is not applicable to printers as they are defined here.

The prepositioned font bar or “tab” technique is capable of printing speeds up to 10 characters per

EQUIPMENT CHARACTERISTICS REVIEW

second, per column. The font bar is arranged in-line on bars or wheels, which are prepositioned so that the selected faces are moved to the printing position and stopped. Then a print bar, which spans the entire line, carries the paper to the type face to make the impression. Prepositioning can be done, either directly through a decoding linkage or by scanning the characters through the print position and stopping the font bar when the correct character is in the print position.

The continuously-moving font bar or "on-the-fly" printer has its character set distributed radially around a type drum which is always moving. A similar arrangement is used in chain or belt printers, where the character set is distributed along an endless belt or chain which is continuously rotating past the print line. Consequently, all of the characters in the set are presented to the print position as the drum or chain makes a revolution. With a numeric character set, this technique will allow printing speeds of 40 characters per second, per column.

Non-impact printing devices take advantage of special papers which are electro-or light-sensitive. Printers using electro-sensitive paper have a stylus matrix in the print head from which current passes through the paper to a ground plate behind the paper. Printers using light sensitive paper depend on an image-forming device such as a CRT and then some type of optical system to transfer this image to the paper.

Excluding the image-forming device, the non-impact printer is fairly simple, however, in light-sensitive printers, the paper usually requires further processing to fix and preserve the image from the degrading effects of ambient light. These printers offer very high speeds (one manufacturer's model produces 6000 lines per minute) and increased reliability due to the elimination of mechanical parts.

EXTERNAL CONSIDERATIONS

Throughput

The first consideration in defining a printer requirement is the capacity or throughput (in characters or lines, per unit-time) required of the machine. This usually determines the type of machine needed and has the greatest influence on cost. A good rule of thumb is to use a "tab" printer if the throughput requirement is less than 150 characters per second, and an "on-the-fly" or optical printer if the throughput is greater than 200 characters per second.

In some applications, a tradeoff can be made between an intermediary buffer and the throughput of the printer. This, of course, depends on the data source and whether data is issued in a continuous flow or in discrete blocks that can be handled by a buffer, but in some cases a larger-capacity printer can be justified in place of a slower machine with a buffer.

The throughput of a printer is determined by the line speed, number of columns or characters per line and, if it is not a direct prepositioned printer, the number of characters in the alphabet or character set. The number of characters in the character set affect the speed because it takes a finite time

to present each character in the set to the printing position when moving-font techniques are used; consequently, the more characters, the slower the speed.

Number of Columns

The requirement as to the number of columns is usually a judgement based on the organization of the printout. This directly affects both the throughput and the cost, as the longer the line the greater the cost of the machine. In many cases, the organization of the printout can be changed to reduce the cost of the printer, and there are a number of combinations of line speed and line length which could satisfy throughput requirements.

Interface

The interface between the printer and the data source is another important consideration. Input data formatting, timing, and device control must be examined along with the mechanical and electrical interface problems.

Input data format is a problem only when the organization of data coming from the source is different from that going into the printer. For example, a serial printer receiving parallel data requires a converter in the interface as does a parallel printer receiving serial data. Converters are usually shift registers or a storage device with commutation or decommutation.

The timing problems involved in connecting a printer to data are often confused by the so-called "asynchronous" operation of the printer. The fact of the matter is that all impact printers are cyclic devices requiring a finite amount of time to print and then to advance paper. Thus, the entry and holding of data must be synchronized to the print cycle. This synchronization can be done in line-storage during the paper phase of the cycle, but attention must still be paid to the print and paper-feed phases of the cycle. If double line-storage is used, the first for synchronization and the second for holding data during the print phase, asynchronous operation can be achieved—providing data is not entered at a rate exceeding that of the printer. Some manufacturers offer interface options which might prove economically useful and should be investigated.

INTERNAL CONSIDERATIONS

The systems user should consider the major design features of various types of printers as they affect reliability, maintainability, and operating costs. The following generalizations will give the reader a "feel" for the problems involved.

Print Mechanisms

The function of the printing mechanism is to bring the selected type face in contact with the paper at the correct time.

In the tab printer, this mechanism positions the font bars. In the direct prepositioned tab printer, this mechanism is the decoding linkage between the solenoids and the font bars. This mechanical linkage is simple but is subject to wear or sluggish

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action due to dirt or lack of lubrication.

The basic positioning mechanism used in the scanning tab printer is a ratchet-pawl assembly where the ratchet is fixed to the type bar and the pawl is used to stop the scanning motion of the type bar at the correct character position. In examining this mechanism, attention should be given to the number of moving parts and the interference that dirt or paper-dust could give to mating parts with tight tolerances. Also, the number of linkages which are subject to wear, and the speed-limiting component of the printer should be investigated.

The higher speed "on-the-fly" printers require an entirely different printing mechanism. This mechanism is generally made up of individual actuators and their associated hammers, one for each character or column in the line. (The actuators are usually solenoids, although in one type of printer, the hammers are interposed, at the correct time, between an actuating cam and the type drum.) The actuation of the hammer must be coincident with the appearance of the selected character, at the print position. In some cases, the individual type faces pass the printing position in less than one millisecond. However, it usually requires a greater time period to actuate and allow for the return of the hammers, and thus the hammers have to be actuated with a preset lead time. As the timing is extremely critical, and individual hammer delays can vary, an adjustment is allowed for in each hammer. This timing adjustment, which shows up in the alignment of the printout, is done in varying ways depending on the mechanism used.

Paper Feed

In "tab" and "on-the-fly" printers the paper must be stopped while printing takes place. Consequently, to advance paper after printing, the paper has to be continuously engaged with a feeding device that is driven incrementally, or the feed device is continuously moving and incrementally engaged with the paper. In the former case, the feed device is usually pinch rollers or sprockets driven by ratchet and pawl assemblies, clutch brakes, or stepping motors. The latter case usually employs a capstan for driving and a controllable idler for engaging the paper with the capstan.

Pinch-roll feed devices are used in most of the printers described in this section as they are simpler and do not require special paper with feed holes. Sprocket feeds are required to hold multi-part paper together and are usually employed for the feeding of wider paper, such as in a page printer. Capstan feeds are frequently used when the paper is relatively narrow, such as in strip printers, because of the paper buckling and skewing problems narrow paper presents.

Wide-page computer printers, printing on pre-printed forms, usually are provided with some sort of forms control to facilitate a greater paper throughput or documentation rate. Forms control is usually implemented through a punch paper loop which tells the printer when to slew paper ahead to the next printing area on the form. Simpler vertical format control is usually accomplished by employing a head-of-form index. This allows paper to be slewed to the head of the next form when printing is finished on the last form.

When multi-part forms (original, plus copies)

are used in the printer, sprocket paper feed systems are required to hold the paper parts together. In high-speed printers, these sprockets are expanded to tractor feeds which give a larger gripping area for high-speed paper slewing. Also, some of these printers use both upper and lower tractors to allow for paper tension adjustment in front of the hammers.

Transfer Medium

Another part of the printer which should be studied is the transfer medium. The most popular medium is the linked ribbon which must be interposed, with the paper, between the font bar and the print bar or hammers, and requires a drive and reversing mechanism. Application of an ink film directly to the type face is done, in some cases, by reservoir-fed rollers, which transfer ink from their surfaces to the type. One manufacturer uses a micro-porous roller where the ink is saturated in the roller and transferred to the surface by capillary action. This type of roller claims to have 10 times the inking capacity of a ribbon.

Several manufacturers have eliminated ribbons by using impact or pressure sensitive paper. This paper forms the image by crushing micro capsules of contrasting dye that bleeds into the paper. Currently, the price of this paper is around three times that of regular paper.

Reliability

Reliability is generally expressed in statistical terms as Mean-Time-Between-Failure (MTBF) which can be derived either from documented failure rates or from a statistically-valid sample of controlled-system life tests. Unfortunately, there are no documented failure rates for the varied mechanical components that go into printers. Consequently, if MTBF figures for printers are to have any meaning, they should be backed up by a valid sample of life tests. It is worth noting that printers (other than the optical types) are mechanical devices and MTBF figures in the order of 1000 hours are very good.

Other factors that should be considered in examining a printer are the ease and frequency of paper loading and ribbon replacement. Also, access to components and requirements for special tools should be reviewed along with the modularity of the system for ease of troubleshooting.

SUMMARY

In order to satisfy the varying requirements of a one-time application or production system designs, most manufacturers will supply the basic printer mechanism or the printer with a basic electronic package. For the one-time situation, it is often more economical to seek out the manufacturer who already has optional interface circuits. It is suggested that the systems designer give first consideration to the throughput requirements of the system before settling on the line length of the printer. This offers a greater selection and opportunity for savings. Once throughput and line length are

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established, printing speeds can be determined and a printing technique selected.

After the choice has been narrowed down, it is suggested that the system designer ask the manufacturer for a demonstration, so that the various design features can be discussed firsthand and an interface can be established. Data sheets usually

leave a lot of questions to be answered. Also, the prospective buyer should try to determine, as closely as possible, how reliable the printer is from supported MTBF figures, or better still, from actual user experience.

The major specifications of available computer printers are presented in the following chart.

PRINTERS

MANUFACTURER MODEL	MAJOR APPLICATION	THROUGH-PUT (char/sec)	MAX. NO. OF COLUMNS	SPEED (Lines/Sec.)	PRINTING TECHNIQUE	DATA ENTRY	BUFFER	APPROX. PRICE	COMMENTS
ANELEX	5000	Computer	3300	160	25	On-the-fly	Char-serial	Line	—
	2400	Communication	400	80	4	On-the-fly	Ser or par	Line	—
	4000	Computer	800	160	5	On-the-fly	Char-serial	Line	—
BURROUGHS	B329	Computer	2300	132	17	On-the-fly	Char-serial	Line	—
CLARY	AN-16	Communication	25	1	—	On-the-fly	Char-serial	No	2
	2000	Logging	210	21	10	On-the-fly	Parallel	No	13
	4000	Logging	315	21	15	On-the-fly	Parallel	No	7.5
	7000	Logging	200	20	10	On-the-fly	Parallel	No	2
COMPUTER MEASUREMENTS	410A	Logging	120	12	10	Segmenter	Parallel	No	1.7
CONNECTICUT TECHNICAL	SP-200	Communication	15	156	—	Tab	Char-serial	Char.	.5
	S-100	Logging	15	13	—	Tab	Char-serial	Char.	.5
	N-100	Computer	10	292	—	Type Bar	Char-serial	Char.	1
FRANKLIN ELECTRONICS	120A	Communication	20	1	—	On-the-fly	Char-serial	No	.3
	1200	Logging	480	12	20	On-the-fly	Parallel	No	2
	1600	Logging	640	16	40	On-the-fly	Parallel	No	2.5
	3200	Computer	640	32	20	On-the-fly	Parallel	No	6
DATA PRODUCTS	L/P M360	Computer	792	132	6	On-the-fly	Par or ser	Block	44
	L/P M600	Computer	1320	132	11	On-the-fly	Par or ser	Block	45
	L/P M1000	Computer	2200	132	17	On-the-fly	Par or ser	Block	50
DI/AN CONTROLS	N	Computer	640	32	20	On-the-fly	Par or ser	Line	6
	DL	Logging	640	16	40	On-the-fly	Par or ser	Line	2.5
	PONY	Computer	640	32	20	On-the-fly	Char-serial	Line	10
	RO-640	Communication	640	32	20	On-the-fly	Bit-serial	Line	10
									Interfaces to PDP-8
HEWLETT-PACKARD	5050A	Logging	360	18	20	On-the-fly	Parallel	—	—
	562A	Logging	60	12	5	Tab	Parallel	—	1.7
IBM	2203	Computer	1870	144	13	On-the-fly	—	—	For System 360/20
	1403N1	Computer	2380	132	18	On-the-fly	—	—	For all System 360 models
	1403-2	Computer	1320	132	10	On-the-fly	—	—	For all IBM computers
	1403-7	Computer	1200	120	10	On-the-fly	—	—	For all System 360 models
	1445N1	Computer	—	—	4	On-the-fly	—	—	For magnetic ink printing
KLEINSCHMIDT, DIV OF SCM.	311	Communication	30	72	—	On-the-fly	Char-serial	—	3.9
LITTON, DATALOG DIV.	MC4000	Logging	3200	32	100	Photo-Opt.	Char-serial	Char. or line	5.8
	MC8000	Computer	8800	88	100	Photo-Opt.	Char-serial	Char. or line	10
MITE	118A	Communication	10	1	—	Tab	Char-serial	No	.4
	AN/UGC-41	Communication	10	72	—	Tab	Char-serial	No	3.5
POTTER INSTR.	PS6020	Computer	1250	132	14	On-the-fly	Char-serial	Line	28
	HSP3502	Computer	1300	132	10	On-the-fly	Parallel	Line	10
	HSP3603	Logging	120	12	20	On-the-fly	Parallel	Line	13
	HSP3601	Logging	276	23	8	On-the-fly	Parallel	No	13
SHEPARD LABORATORIES	802	Logging	80	2	40	On-the-fly	Par or ser	Char. or line	1
	848	Logging	1920	48	40	On-the-fly	Par or ser	Char. or line	9
	990	Computer	1600	80	20	On-the-fly	Par or ser	Char. or line	15
	400	Computer	4000	200	20	On-the-fly	Par or ser	Char. or line	30
SPECTRA-STRIPE, REO DIV.	P8000	Logging	48	24	2	On-the-fly	Parallel	No	1.2
TELETYPE	32	Communication	10	80	—	Tab	Char-serial	No	.6
	33	Communication	10	80	—	Tab	Char-serial	No	.6
	35	Communication	10	80	—	Tab	Char-serial	No	2.5
									Heavy Duty

PUNCHED CARD EQUIPMENT

The punched card is so common an item that its applications and usefulness need not be documented in detail; it is familiar to nearly everyone, and its applications are so widespread as to defy cataloging. Variations in the form and size of the cards are many; however this survey is limited in scope to devices which read data from, and punch data onto, the overwhelmingly most popular version, the 3-1/4" x 7 3/8" card, generally known as an "IBM card". This card has eighty columns, twelve rows, and square holes.

The equipment for punching and reading cards can be categorized as follows.

1. Automatic card readers: a stack of cards is placed into a feed hopper, and the reader selects one at a time for reading; cards leaving the read station are accumulated in one or more stacker-bins.
2. Static card readers: one card at a time is manually placed into the read station.
3. Card punches (usually automatic): a stack of blank cards is placed into the feed hopper, and the punch selects one card at a time for punching; cards leaving the punch station are usually collected in one stackerbin.
4. Card reader-punch: A single machine that performs both the reading and punching operations.

Automatic Card Readers

The major selection factors of an automatic card reader are as listed.

■Reading speed.

■Number of hoppers and their capacity.

■Checking features:

1. Misfeed—card did not enter reading station;
2. Validity checking—an incorrect character is read;
3. Read checking—double-checking the data read.

■Method of reading:

1. Contact reading—current-carrying brushes or pins sense the presence or absence of holes;
2. Non-contact reading—photoelectric, fiber optic-photoelectric, or air-jet sensing units are used.

■Character-read or row-read—cards are scanned either a column (character)-at-a-time or a row-at-a-time. The latter results in faster reading (since there are only 12 rows versus 80 columns), but it requires that the card be re-oriented (corner-turning) in order to read all the characters.

Automatic card-reading equipment is supplied in varying degrees of complexity, from a read-head only to a complete unit with hoppers, code translators, and appropriate interfaces.

The product summary charts following this text list the major characteristics of commercially-available automatic card readers, punches, and reader-punch combinations.

Static Card Readers

The static card reader is used primarily as a programming device and is functionally a read-only 80 by 12-bit memory in which the storage element (the card) can be replaced. Static card readers use contact (pin or brush) reading, and usually read all 960 positions simultaneously.

Since it is difficult to tabulate the characteristics of commercially-available static card readers in chart form, these units are discussed in the following text.

AMP Incorporated of Harrisburg, Pa. provides a complete line of manual card readers. The Amp Syscom Card Reader consists of 960 single-pole, single-throw switches that may be commoned in innumerable ways with the use of standard pre-punched tabulating cards. The switches are controlled by a single actuating handle. With the insertion of the card and moving of the actuating handle to the "read" position, contact springs above the card pass through punched areas to the printed circuit card below to complete the desired circuits. The reader serves as a multi-pole, multi-position switch which permits an unlimited number of programs to be processed with the substitution of one card for another. Three pre-wired models are available from Amp.

■Model 1041 is a matrix type with an 80-column, 12-row matrix configuration which provides for connecting any of 12 inputs to any of 80 outputs, any of 80 inputs to any 12 outputs, all inputs to one output, or any input to all outputs.

■Model 1042 features 80 input columns with 960 individual outputs or 960 individual points with 80 outputs. Each of the 80 inputs can be connected to any or all of the 12 outputs.

■Model 1043 is basically a Model 1041 with diode isolation to eliminate alternate and unwanted circuit paths.

Sealectro Corporation of Mamaroneck, New York, offers a static card reader which has 960 independent switches (12 x 80 column format) with bussed or discrete inputs. All outputs are discrete. The unit will accept only properly-oriented cards. An automatic card tray draws the card into the read position and ejects card after reading.

Philco, of Willow Grove, Pa. offers a card reader designed for use in environments with assembly line atmosphere and featuring reliability of compo-

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nents and a MTBF of 12,000 hours.

Another unique unit is built by Jordan Controls, Inc. of Milwaukee, Wisc. The PC-3100 is a static card reader with direct analog output allowing direct card programming for analog control or position systems.

The Taurus Corporation of Lambertville, N. J. has over 17 different models of punched card programmed switches. These models are of two major types: Type K (Remington Rand cards) and Type M (IBM cards). Current carrying capacities are 2 to 3 amps.

Datron Systems, Inc. of Mountain Lakes, N. J.

offers a low-speed card reader that functions directly with the Bell 401 Dataphone sets. Called the Model 610 Data Transmission Card Reader, the unit consists of a manually-fed serial card reader, an optional keyboard, and an interface. The code transmitter, for data as well as functions, is fully compatible with most key punches used as output devices in data phone transmission systems. The 610 Reader is a direct replacement for less flexible data sources now used in such systems. It will transmit as much alphanumeric data as may be punched in a card up to a full 80 columns. Reading speed is 10 columns per second.

AUTOMATIC CARD READERS

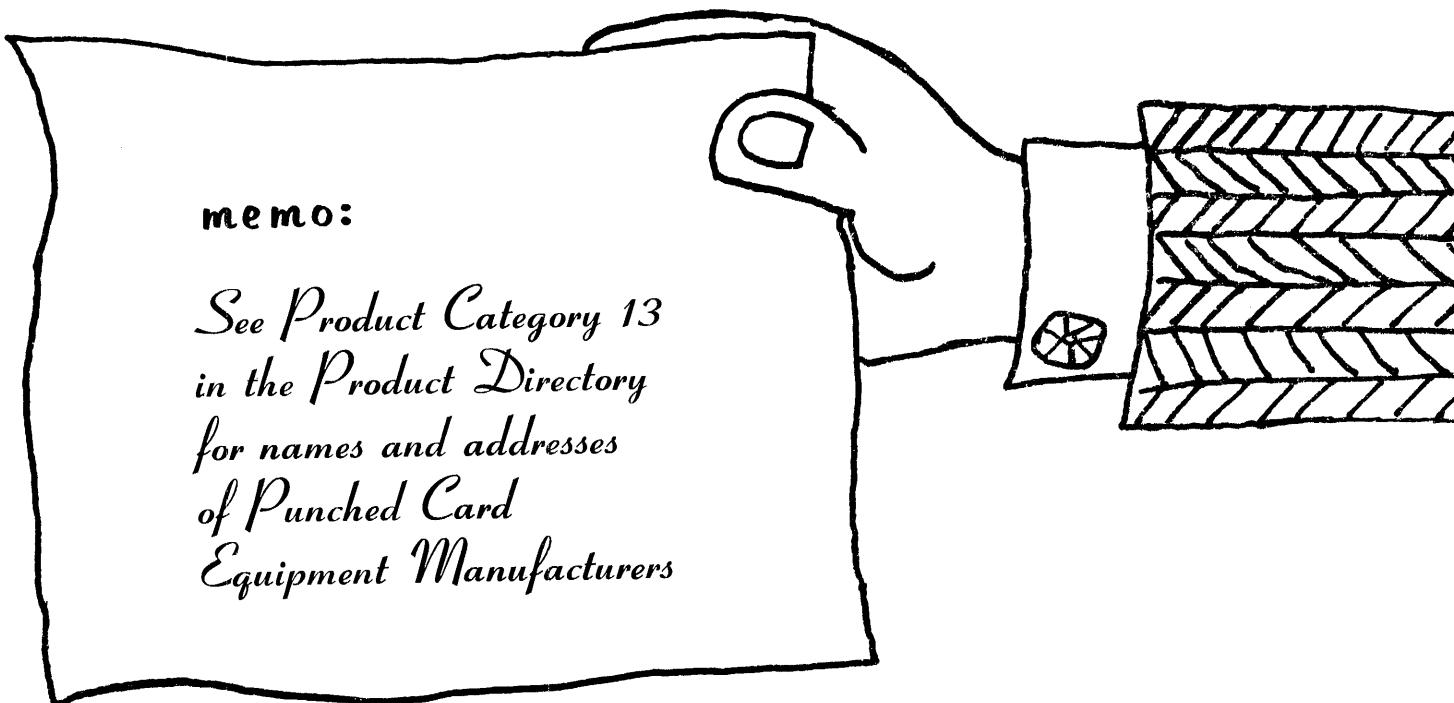
MANUFACTURER	MODEL	READING SPEED (cards/minute)	HOPPER CAPACITY	No. OF STACKER-BINS	STACKER-BIN CAPACITY	CHECKING FEATURES	APPROX. PRICE	COMMENTS
BURROUGHS	BC 129	475/800/1400	4000 cards	1	4000 cards	Dual read, misfeed detection, validity checking read checking	12.9	
	BC 122	200	500 cards	1	500 cards	Misfeed detection validity checking read checking	3.595	
CONTROL DATA	405	1200/1600	4000 cards	1	4000 cards	Dual read, misfeed detection	22	Photoelectric sensing; optional card reject stacker-bin avail.
	9200	1200	4000 cards	1	4000 cards	Dual read, misfeed detection, timing check		Photoelectric sensing
DIGITAL ELEC. MACHINES	CRU-D55	55					2.8	Photoelectric sensing; interfaced to data phone
FRIDEN	ACR	572	200 cards	1	200	Misfeed detection	2.995	
HONEYWELL EDP	223	800	3000 cards	1	2500 cards	Validity checking, timing check		Photoelectric sensing
NCR	EM-D1	2000	5000 cards	1	5000 cards	Validity checking		Photoelectric sensing
	EM-D2	100	430 cards					Star-wheel switch sensing; photoelectric sensing version avail.
SOROBAN	ERS-1	1100/1250	2000 cards	1	2000 cards	Validity checking	11.9	Compact console with 1000 card bins avail; optional reject stacker-bin avail; photoelectric sensing
	ERC-1	1100	1000 cards	1	1000 cards	Validity checking	6.5	Photoelectric sensing
UNIVAC	0704	400	1200 cards	3	1000 cards	Misfeed detection	4.5	
	2007	615	1200 cards	1 or 3	1500 cards	Misfeed detection	2.7	Reader mechanism only
	0706	600/800	2500 cards	1	2000 cards	Misfeed detection	7.5	Optional card reject stacker-bin avail.
UPTIME	SR-400	400	1400 cards	1	1000 cards	Transport check, stacker jam check, misregistered check, photodiode check	5.73	Photoelectric sensing
	SR-800	800	2500 cards	1	2000 cards	Same as SR-400	8	Photoelectric sensing; optional card reject stacker-bin avail.
	SR-1500	1500	2500 cards	1	2000 cards	Same as SR-400	12.75	Photoelectric sensing; optional card reject stacker-bin avail.

AUTOMATIC CARD PUNCHES

MANUFACTURER	MODEL	PUNCH SPEED (cards/min.)	HOPPER CAPACITY	APPROX. PRICE (\$000)	COMMENTS
BURROUGHS	B303	100	800 cards	—	
	B304	300	3500 cards	—	3 output stacker-bins
IBM	2520 A2/B2	500	—	—	
	2520 A3/B3	300	—	—	
INTERNATIONAL COMPUTERS AND TABULATORS, LTD.	582	100	800 cards	2.058	Mechanism and hopper only
SOROBAN	EP-4	400	NONE	9.685	Head only
	EP-4 CON	400	2000 cards	19.5	
	EP-4C	200	—	15.5	Compact version of EP-4
UPTIME	120	120	1000 cards	—	

CARD READER-PUNCHES

MANUFACTURER	MODEL	READ SPEED (cards/min)	PUNCH SPEED (cards/min)	INPUT HOPPER CAPACITY	OUTPUT HOPPER CAPACITY	COMMENTS
HONEYWELL	224	300/400	50/91	1200 cards	1300 cards	2 output bins
	227	800	250	3000 cards	1000 cards	3 output bins
	214-2	400	400	1200 cards	1300 cards	
IBM	2540	1000	300	—	—	
	2520A1/B1	500	500	—	—	
	1442 N1	300	91	—	—	



PUNCHED TAPE EQUIPMENT

Long before the development of general-purpose digital computers, punched tape was an important media for the transmission and recording of messages. Now, with the wide-spread use of digital computers and digital techniques, punched tape has become even more important. Punched tape equipment includes readers, perforators, keyboard perforators, tape handlers, and related accessories. All of these products are discussed in this section.

APPLICATIONS

The low cost, simplicity, and reliability of paper tape equipment account for the popularity of paper tape as an input-output and recording medium. The usefulness of punched tape was first demonstrated in the communications field when manual telegraph methods were automated by coding messages on paper tape for transmission over telephone lines. Incoming messages were also coded in punched tape format. The purpose, of course, was to minimize errors and to reduce costs by reducing transmission time. Communications still represents one of the major areas of application of paper tape equipment. A more detailed discussion of paper tape terminals is included in the section entitled "Data Communications Terminals and Special Processors".

Continued improvements in the design of perforated tape readers, punches, and tape handlers have led to a much broader range of applications, many of which were previously handled by punched cards and magnetic tape. Some of the major applications reported by equipment manufacturers and by suppliers of punched tape and related accessories include:

- Numerical control;
- Input-output for digital computers;
- Automatic message transmission and recording;
- Automatic testing;
- Data collection.

The machine tool industry is one of the leading users of punched tape systems for numerical control. Significant cost savings are possible by using punched tape for controlling machining and metal-working operations such as reaming, milling, cutting, drilling, positioning, boring, and welding. After reducing an engineering drawing to a master control tape, a metal blank can be machined to a finished part. When programmed by punched tape, a machine tool can operate more economically by reducing unnecessary wear on cutting tools and by minimizing waste material.

Process control involves operations which are more complex than those encountered in numerical control. Hence, perforated tape plays a less significant role. However, in simple operations such as wrapping, blending, and packaging, paper tape systems may serve as control stations. In more complex process control applications where multiple

parameters must be controlled or sampled simultaneously, multiple tape reading stations or perhaps a general-purpose digital computer would be required.

In automatic test equipment, test routines are coded on punched tape to allow precise repetition of tests without deviation and with a minimum of error. A single part or an entire production lot can be subjected to identical tests without the variances inherent in manual testing. Acceptable tolerances can be coded on tape for comparing with the test data of the item undergoing inspection. Complete systems can also be exercised or tested using similar punched tape control techniques.

Punched tape is used extensively as an input medium in general-purpose digital computers and business data processors. Punched tape equipment has cost and speed advantages over card equipment. Tapes are prepared at a relatively slow speed, on-line or off-line. However, once prepared, they may be read at high speeds, thus minimizing the computer time consumed while entering data.

In tele-communication systems, messages are coded on tape for automatic transmission over ordinary telephone lines. Incoming messages can also be recorded in punched tape format from which printed copies are subsequently made. This eliminates the time-consuming re-writing of incoming messages. A punched tape-operated transmitter-receiver, which operates with standard telephone lines, is used to automate a number of business and sales office tasks such as order-writing, invoicing, shipping, and inventory control.

READERS

Punched tape readers are broadly classified as either mechanical or photoelectric depending upon the method used for sensing punched holes. Mechanical readers are used in low speed, usually less than 30 characters/second (cps), reading applications, while photoelectric readers dominate high-speed reading applications. In photoelectric readers, the tape is usually edge-guided, while in mechanical readers, sprocket wheels are used for tape alignment and guiding. Regardless of the method used for hole sensing, the internal organization of most readers is based on similar logical design and amplification principles.

Reading speed is usually specified in characters per second or lines per second, both of which are identical. Tape reader manufacturers will generally specify the maximum speed attainable when reading continuously (synchronously) as well as the maximum line-at-a-time (asynchronous) speed. Block readers, on the other hand, read many lines of information simultaneously, therefore, reading speed is measured in blocks per second or perhaps milliseconds per block. Tape advance methods, inertia, and contact bounce limit the speed of most mechanical readers to less than 30 char/sec. A few photoelectric

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readers have been designed for speeds up to 1000 char/sec; however, most current photoelectric reader applications are in the 200 to 500 char/sec. Photoelectric reading speed is limited only by the response time of the photocell and by the tape transport mechanism.

Naturally, cost goes up with speed; therefore, prospective users must carefully determine speed requirements for each individual application before making commitments. There are a multitude of tape reader applications, particularly in machine tool control test equipment programming, and tele-communications where high speed is often unnecessary, unwarranted, or perhaps even undesirable.

Stopping the tape motion, which can be accomplished upon sensing a STOP code punched in the tape, is a relatively simple matter in mechanical readers. In high-speed photoelectric readers, braking distance is a function of transport speed and must not "overshoot" the next character to be read or expensive buffer memory stages will be necessary. At speeds up to 500 char/sec., the tape can be stopped on the STOP code. At higher speeds, the tape will come to rest between the STOP code and the next character to be read. The stop time is usually less than 1 millisecond in currently available photoelectric readers.

Mechanical Readers

Mechanical readers detect perforations when electrical contacts are made through the holes by spring-loaded pins, star wheels, brushes, forced air or similar techniques. Due to inertia, contact bounce, and sprocket-guiding methods, most mechanical readers operate more reliably at slow speeds. Moving contacts must be constructed with special alloys or precious metals to eliminate wear and to provide high resistance to corrosion. An important consideration in all types of readers is tape life which is measured by the number of passes through the reading head. To increase the tape life in mechanical readers, paper tape (generally capable of 300 passes) can be replaced by other materials such as paper-coated Mylar, or Mylar-coated foil which can withstand up to 50,000 passes.

Mechanical sensing pins represent one of the simplest and most common sensing methods in use. Spring-loaded pins or brushes travel along the surface of the tape making contact as holes pass beneath the pins. This technique is sufficiently reliable at low reading speeds (about 10 char/sec.) and is quite economical since pin retraction circuitry is not required. Pin sensing allows continual reading accuracy even when the tape becomes worn or when hole-to-hole tolerance exceed EIA Standards. Longer tape life and less contact wear is possible with retractable pins which do not rub against the tape while the tape is in motion. However, an obvious design problem with retractable pin mechanisms is that of providing a positive means of preventing tape motion during the read cycle. The timing of pin retraction and tape advance must be coordinated to prevent damage to the reader and the tape.

Star wheel sensing is another mechanical sensing technique. This type of sensing requires one star wheel for each tape channel to be read. One type of star wheel mechanism is designed so that the presence of two successive holes or no-holes in the same channel allows the star wheel carrier arm and its

corresponding wire contact to remain in position. When one of the points of a star wheel centers a hole, an arm carrying the star wheel closes a switch.

A unique sensing technique which employs forced air is used in tape readers manufactured by Soroban Engineering Inc. This technique permits reading speeds up to 350 char/sec. The reading head operates reliably in severe industrial and military environments. The fluid-flow method allows contactless reading of chadless tapes, dry or lubricated papers, transparent or opaque paper, or even perforated plastics. Fluid-flow sensing of perforated tape is accomplished by passing the tape in front of high-pressure air jets. The tape acts as a valve as it is passed across a row of air jets. Air is allowed to pass when a perforation is present, and the air is deflected or blocked when a no-hole condition occurs. Ported air is directed through a "Venturi" throat thus drawing additional air through an induction passage and over a hot-wire sensing element. The hot-wire sensing element functions as one leg of an electrical bridge circuit. Air flow, caused by a perforation, cools the element and tends to unbalance the bridge thereby producing an error signal.

Photoelectric Readers

Photoelectric readers employ light-sensitive elements to detect punched holes. The sensing elements are triggered as light is transmitted through a hole or as in some readers, when light is reflected from a no-hole area. Photoelectric readers are capable of speeds up to 1000 char/sec. Photocell response and tape transport mechanisms are usually the only considerations which might limit reading speed.

The cost of photoelectric readers has been reduced significantly in the past few years as a result of several important design improvements. In the past, expensive circuits were required to reduce drift in photodiodes and amplifiers. Also, intricate devices for insuring accurate optical alignment of each cell as well as the overly-elaborate tape transport mechanisms contributed to the high cost.

Now, simplified tape transport designs, ac coupling of amplifier circuits, and photovoltaic detectors have allowed major price reductions of photoelectric readers while improving accuracy and reliability.

A typical photoelectrical mechanism uses a single silicon photovoltaic cell with nine separate elements for sensing. The photovoltaic cell converts light energy directly into electric energy. The nine elements provide eight data channel outputs and one strobe channel output for use with standard five-, seven-, and eight-channel tapes. The individual sensing elements can be made from the same silicon sample to minimize variations from element to element. As with all photocell readers, there are no reading contacts to wear out or to produce spurious signals due to bounce.

The leading edge of the sprocket hole is used to initiate the sampling of the data channels. Since data holes are larger in diameter than sprocket holes, yet have a common longitudinal centerline, data holes are optically aligned for reading by the time the edge of the sprocket hole comes into view. A transistor amplifier associated with the sprocket channel is used to strobe the data channels thus permitting simultaneous reading of all holes appearing in a single row.

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When photodiode lenses, consisting of synthetic rubies in some readers, protrude slightly above the surface of the reading head, the motion of the tape continually removes dust particles from the photo-cells. This self-wiping feature is particularly advantageous in machine shops and other industrial and military environments where fine particles of dirt and dust often cause reading errors.

Signal-to-noise ratio is another important consideration in photocell sensing. To achieve and maintain a maximum signal-to-noise ratio, tape transmissivity should be low (40% is adequate), and the tape should be free of any defects. Also, the lamp voltage should be stable to assure consistent photodiode response.

The reflected light technique uses a point light source which is focused on the tape through a spherical lens and a cylindrical lens. Light reflected from a non-hole area is sensed by silicon photocells. Code sensing depends on the difference in light reflected from a hole and a non-hole area as the tape passes beneath the light columns. Reflected light sensing, unlike direct photocell sensing methods, permits the reading of both punched and printed tapes. Another important advantage is that transparent, opaque, pastel or dark colored, and translucent tapes can be read interchangeably without requiring photoamplifier adjustments. One of the few readers employing reflected light sensing is the Omni-Data readers manufactured by General Electric Printer/Reader Section (formerly Omnitronics, Inc).

Dielectric Sensing

A rather unique sensing technique developed by a Swedish firm, Facit, is called "dielectric reading". The punched tape forms the dielectric of a capacitor whose capacitance is changed as a hole passes the read station. Unlike photocell sensing, dielectric readers are insensitive to environmental dust and low-quality paper. Also, since lamps and photocells are not used, there is no problem of long-term drift and aging.

Block Readers

Block readers are capable of reading a large number of bits simultaneously. With block reading, there is no need to buffer or accumulate data in a register or storage device. Control points can be monitored directly with the output of block readers since there is no intermediate accumulation, storage circuitry, or address circuitry. Identification of data by position within a block eliminates the need for address circuitry since the reader itself can perform routing and address decoding. Automatic test systems frequently employ block readers. A single 80-bit block or frame can represent a complete test. Several tests can be sequenced each second while each bit within a block directly controls one of 80 control points.

Block readers are available with sensing as well as photo-sensing elements. The reading speed of block readers depends on the number of lines of information within the block. A typical block reader may be designed to read 20 lines, therefore, if eight-channel tape is used the size of the block would be 160 bits.

The product summary charts following this section

contain a comparative listing of commercially-available paper tape readers. In these charts, the major performance characteristics of typical readers are summarized.

TAPE PUNCHES

Paper tape punches have been in use for many years as data recording devices. In the past few years, there has been a sustained increase in the number and variety of tape punch applications. This increase is due in part to design improvements and in part to demands imposed by new applications. Although punches are commonly referred to as "paper" tape punches, almost all commercially-available units are capable of punching other materials such as Mylar, paper-coated Mylar, etc.

The application areas for tape readers were discussed previously and they obviously apply to the punches. Broadly categorized, today's major applications include computer output, data logging and data acquisition, message and data communications systems, numerical control, and automatic testing operations.

Punched tape has many advantages over other recording media. It is less expensive and less vulnerable to variations in moisture and temperature. In contrast to magnetic tape, punched data cannot be erased.

Basic Punch Designs

There are many differences in the basic design of tape punches currently being marketed, while tape dimensions, hole codes, and channel capacities (5, 6, 7, or 8) remain standard. The basic function of the punch, of course, is to react to incoming pulses by activating punch pins which are forced through paper, Mylar, vulcanized fiber, or aluminized tape. The particular punch pins to be energized correspond directly to the bit configuration of the character to be recorded.

The perforating action of tape punches dictates an electromechanical design approach requiring special consideration for the inherent problems of inertia, vibration, noise, and mechanical wear. As punching speeds increase, punch design problems become more acute. For example, in a 300 char/sec. punch, shaft rotation rates up to 9,000 rpm are likely with feed shafts rotating up to 18,000 rpm. Also, at this speed, one cubic inch of chad (confetti) forms every 6 seconds when punching 8 channels. Removing the chad so that it does not clog the punch mechanism is a necessary precaution.

Frequently used devices for activating punch pins are listed below.

- Solenoids — Solenoid-actuated punch mechanisms employ one solenoid for each channel and one for punching the sprocket hole. Also, the functions of bail and transport each require two solenoids. A maximum of 13 solenoids would then be required for an eight-channel punch.

- Reciprocating Cams — The reciprocating motion required for cycling the tape feed and punching operations can be accomplished by the use of triangular cams

EQUIPMENT CHARACTERISTICS REVIEW

driven from a constant rotational power source.

- Electromagnets – Roytron, has a patented scheme which uses the holding power of small, efficient, electromagnets combined with off-center springs to activate the punch pins. The electromagnets require less than 2 watts for up to 50% of duty cycle at up to 3000 RPM of main shaft.

- Clutches – Punch mechanisms controlled by motor-driven clutches are offered by Tally Corp.. The clutches are activated by a pulse which is simultaneously applied to electromagnets. When the electromagnets are energized, the clutch assembly rotates one-sixth of a turn causing the satellite gear on the clutch periphery to rotate and thereby force the corresponding punch pin through the paper.

- Tuned Reeds – A unique tape punch developed by Teletype Corp. does not require energy from a motor to punch the tape. Instead, this energy is stored in a tuned reed while it is attracted to a magnet. The reed (a steel bar) and its associated magnet and electronics are tuned to operate as a unit at a certain frequency. A reed is linked to a punch pin for each code level. When the reed is released by its respective magnet, the punch pin is driven through the tape. The mechanism is capable of operating at any speed up to 200 char/sec.

The product summary chart following this section provides a comparative listing of currently-available tape punches.

Punch Selection Considerations

To satisfy user requirements, most manufacturers offer basic punch mechanisms with or without housing, feed and take-up reels, drive mechanism, and interface logic. This is advantageous for those users who intend to interface the punch with other equipment which is capable of providing mechanical drive and timing. This flexibility also satisfies the needs of the users who require a punch complete with timing drive, logic, amplifiers, and mounting hardware.

System designers consider punching speed one of the most important functional characteristics when selecting a punch. The commercially-available punches discussed in this section operate at speeds ranging from 10 to 300 char/sec. The slow-speed (10 char/sec.) units are generally interfaced with electric typewriters, page printers, and other keyboard devices which are used when an operator is preparing tapes. For recording output data from a computer, acquisition system, or data logging devices, medium- or high-speed (60 to 300 char/sec.) perforators are usually required. If a 10 char/sec. punch is used to produce an object tape as a computer output, it is conceivable that the punching operation would take a few hours for a program of a few thousand instructions. The additional cost for a faster punch (in many applications) is certainly warranted when considering the attendant savings in computer output time.

Although some punches can be adjusted to punch

either 5, 6, 7, or 8 channels, the 8-channel codes offer greater storage capacity as well as parity checking. Until recently, 5-level codes were used extensively in communications equipment. Now, however, 8-level ASCII code is an American standard. In the graphic arts industry, 6-level tapes with advanced feed holes are commonly used. In selecting the channel capacity, the system designer must consider code compatibility implications in order to avoid expensive buffering and code conversion equipment.

To maintain recording accuracy, punches are available which sense parity errors before punching and then inhibit punching when a parity error is detected. Parity checking is generally offered as an option and is not usually included as a standard feature. Other error detecting features are broken tape sensing and out-of-tape sensing.

The ability to activate the punch automatically under program control (on-line) or manually (off-line) from a keyboard or other code selection device is a feature often required in computers and digital data recording systems. Some punches are ideally suited to this type of system integration, while other punches are primarily designed for off-line tape preparation.

Tape feed reels are generally included as standard items with the punch, however, take-up reels and spoolers are usually offered as options. Reversing the direction of the feed reel is possible in some punches to permit code deletion and tape editing, but punching is done in one direction only.

A wide variety of packaging schemes is offered by the punch manufacturers in order to satisfy diversified systems and OEM requirements. The user can usually specify whether the basic punch mechanism is to be rack-mounted, or supplied in a desk-top package, or console housing. Before selecting the packaging scheme, the system designer must consider the problems of chad disposal and air in-take locations for proper cooling.

TAPE HANDLING EQUIPMENT

Tape winding, spooling, braking, and tension-control features are important considerations in the selection of paper tape readers even though these functions may not be directly associated with the reading process. Therefore, this section would not be complete without some mention of tape handling equipment.

All tape reader manufacturers, with a few exceptions, offer tape handling equipment either as options or as integral items. In selecting these additional features, the systems designer must weigh the advantages as they relate to his particular application. There are many tape reader applications which do not require reading lengthy program tapes. And, in many of these cases, slow-speed readers without additional tape handling devices adequately satisfy the requirements of the system and the user.

High-speed readers, on the other hand, are used to their full advantage when reading long tapes at speeds in the vicinity of 300 characters per second. When tape readers are used as an input device to a computer or data processing system, program tapes frequently exceed 200 feet in length. The likelihood of tape damage due to fouling, abrupt starting and stopping, and repeated handling becomes greater as

EQUIPMENT CHARACTERISTICS REVIEW

the tape length and reading speed increase. Consequently, provisions for tape handling and braking become more crucial in high-speed reading of relatively long tapes. The four most common tape handling configurations are listed below.

- Single, motor-driven reel with no tension control mechanism – This is used with slow-speed readers for feeding and rewinding tape. A basic design may consist of a uni-directional motor which is disengaged during the feed operation and is energized only for re-winding the tape.
- Dual, motor-driven reels with simple, tension-arm control – One reel serves as the winder and the other serves as the un-winder. Each has its own tension-arm. When the tension-arm of the winder is forced from its normal position, the winder motor is energized and begins pulling tape. The tension-arm associated with the un-winder merely controls the tape feed rate by stopping the motor when excessive tape slack is detected.
- Spooler units with multiple position tension-arms – Spooler mechanisms consist of a take-up reel and a feed reel each driven by a separate, bidirectional, torque motor. Since the reader accelerates and decelerates the tape at rates much faster than the motor-driven reels, intricate tape tension control devices are required. As the tape tension varies, the tension-arms travel back and forth in a curved path. Depending on its position along the curved path, the tension-arm will signal the associated reel motor to stop, produce full take-up torque, or produce full feed-out torque. In this manner, the tension control devices serve as mechanical buffers between the reels and the reader.
- Servo-controlled reels – This device provides continuous control of tape tension using variable torque motors. Unlike the spooler units whose tension-arms sensed only three control zones along their curved paths, the servo-type tension-arms continuously provide control signals to their reels.

Keyboard Perforators

The previously-described tape punches generally function as an output or recording device controlled by a computer or data processing system. This type of punch, primarily intended for integration into a data system, operates on data pulses coming from outside sources.

Another type of punch is the kind associated with keyboards and typewriters. The drive pulses required to activate the punch are generated by the keyboard. This type of device generally consists of a slow-speed reader, punch, and typewriter. They can be used on-line as an input or output device with a computer, or they may be used off-line to prepare and edit tapes. A printed copy of a program or message is generally produced while the paper tape is being punched. Some units are used

for the purpose of automating letter typing. Examples of this type of keyboard-reader-punch are offered by Dura Business Machines, Friden, and Invac. When used in this fashion, these machines eliminate the need for repetitive typing of identical letters and forms. Keyboard perforators are also discussed in other sections of CI ANNUAL under the following subjects:

- Data Communications And Special Processes;
- Input-Output Typewriters And Keyboards;
- Data Printers.

Another type of perforator associated with a keyboard is a data collection unit manufactured by Addo-X, Inc. The Addo-X system consists of an accounting machine, a card-programmed tape punch, and a check digit verifier. Customer orders, product codes, invoice numbers, etc. are entered via the keyboard of the accounting machine. At the same time, the tape punch automatically records data which is to be transferred to other departments for further processing.

The Friden model AP-6 is a 10-key adding machine combined with a tape punch. The AP-6 provides a printed tape for proof copy, and also features a removable program panel which permits the operator to select either a 5, 6, 7, or 8 channel code. An optional account number verifier is also available with the AP-6 which checks the validity of an account number before it is recorded in the punched tape.

PAPER TAPE SUPPLIES AND ACCESSORIES

For effective utilization of paper tape equipment, a variety of accessory devices and consumable supplies are available. Proper selection of tape supplies and accessories could contribute substantially to convenient trouble-free operation. Included in this class of products are reels, splicers, winders, tape, correction materials, tape holders, and storage containers. Suppliers of all the various types of paper tape accessories are listed in the Directory of Products and Services.

Reels

Paper tape reels are available in sizes from 8 inches up to 14 inches (outside diameter). Models are available to accommodate tape widths between 1/2 inch and 2 inches. Most reels are made of strong, lightweight materials such as aluminum or plastic. Removable flanges are almost essential to facilitate loading and removing tape.

Splicers and Portable Punches

For correcting or changing code patterns already punched or for repairing damaged tapes, portable splicing devices are available. A correction seal or patch is first applied to the area to be modified. The splicer may or may not be adapted with a punch mechanism. The units adapted with punches generally have feed hole pins and sequences to insure

EQUIPMENT CHARACTERISTICS REVIEW

PERFORATED TAPE READER SPECIFICATION GUIDE

As a means of summarizing the major characteristics as well as the more subtle features of punched tape readers, a specification guide is presented here as a checklist for systems designers.

Since an attempt was made to cover all possible combinations of design features, there may be a few categories listed which are not applicable to a particular off-the-shelf reader.

Mfgr:

Model:

Unit Price:

READER OPERATING CHARACTERISTICS

Reading speed:

Max. speed (continuous) char/sec

Max. speed (line-at-a-time) char/sec

Block reading speed blocks/sec

..... Lines/block Channels/line

Tape (EIA Standard) channel capacity:

5....., 6....., 7....., 8.....

Channels read interchangeably:

5....., 6....., 7....., 8.....

Reader adjustments required to change from one channel capacity to another:

Tape acceleration time: milliseconds

Tape deceleration time: milliseconds

Minimum time between tape movement commands milliseconds

Reading directions available:

..... unidirectional, bidirectional

Broken tape sensing: yes, no

End of tape sensing: yes, no

Tape stopping characteristics:

..... Stop on STOP character at speeds up to char/sec

..... Stop between STOP character and next character at speeds up to char/sec

SENSING ELEMENT

..... Photocells (direct sensing)

..... Photocells (reflected light sensing)

..... Sensing pins, bounce time (milliseconds)

..... Star wheels, bounce time (milliseconds)

..... Dielectric

..... Fluid-Flow Other

TAPE CHARACTERISTICS

Tape recommended by reader manufacturer:
..... paper, Mylar, Mylar-paper combination, lubricated paper,
..... other (pastel, dark-colored, opaque,
translucent, etc.)

Tape thickness requirements: inches

Maximum transmissivity allowed: percent

TAPE TRANSPORT

..... pinch roller and capstan

..... sprocket wheel

Drive motor: supplied with reader
..... option

Tape guide method: edge-guided
..... sprocket indexed

READER PERFORMANCE

Tape Life: (no. of passes) using
(type of tape)

..... (no. of passes) using (type of
tape)

MTBF: hours

Reliability: errors per bits read

Applicable MIL Specs:

Operating temperature range:

Pressure:

Relative humidity:

Shock and vibration: G (impulse)
..... G (vibration at cycles/sec)

Elevation (airborne applications) feet

MECHANICAL CHARACTERISTICS

Dimensions (overall):

Weight:

Mounting: Panel Console
..... Desk

Mounting orientation: horizontal
..... vertical no mounting restrictions

ELECTRICAL CHARACTERISTICS

Drive motor requirements: hp rpm
..... power requirements

Installation power source requirements:

Reader output voltages: hole no
hole

TAPE HANDLING EQUIPMENT

Standard Option Item

..... Winders: inches/sec,
reel diameter inches
..... Spoolers: inches/sec,
reel diameter inches
..... Servo-controlled
reels inches/sec,
reel diameter inches

EQUIPMENT CHARACTERISTICS REVIEW

proper alignment prior to punching the new codes. The splicer unit is also convenient to use as a portable punch when access to high-speed, automatic punch is not possible.

Some of the major suppliers of splicers and portable tape punches are: J.H. Bunnel & Company, Burroughs Corp. (Component Sales Dept.), Data-Link Corp., and Robins Data Devices, Inc.

Winders

Several types of tape winders are available for re-winding and transferring types from reel to reel. These units are portable and may or may not be motorized. Many of the low-cost computers do not have provisions for tape handling even though paper tape may be the primary input-output medium. Winders are quite useful for preventing tears and tangles in the paper tape. The basic winder is a manually-operated portable unit or it may be equipped with a small motor. Some computers do have spoolers or automatic tape take-up provisions, as integral units. A separate, motorized winder is available which can be positioned next to the computer for direct take-up of punched tape. Units of this type are manufactured by Cycle Equipment Company and Robins Data Devices, Inc. These units generally include tape tension-arms which control the speed of the winder. The winder automatically stops when the tape becomes taut, and it starts automatically when tape is fed.

Paper Tape

The term "paper tape" is used here as a generic word but most perforated tape is actually Mylar, paper-coated Mylar, vulcanized fiber, or aluminum. Standard tape widths are 11/16, 7/8, and 1 inch.

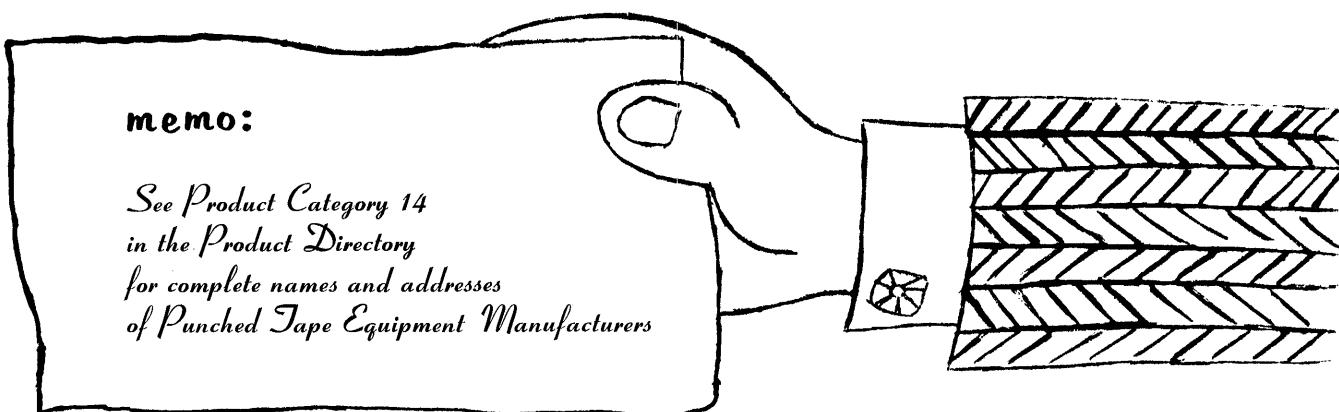
Tapes which are used in numerical control applications must withstand repeated usage, and therefore, should have a high tensile strength, tear strength and must be within allowable limits of shrinkage and elongation. A few of the key suppliers of perforated tape include Chase-Foster, Inc., Arvey Corporation, Robins Data Devices, Business Supplies Corporation of America, and Paper Manufacturers Company.

Correction Seals

Correction seals or splicing patches are used to repair torn tape or to modify previously punched holes. The seal has adhesive material on one side and it generally has greater tensile strength than the paper to be corrected. The patches may be used on any type of tape including paper and Mylar.

Storage Devices

Any computer system that operates primarily on perforated tape as an input-output medium, will eventually accumulate several thousand feet of program tapes. Typical programs coded on punched tape include loader routines, diagnostic routines, assemblies, compilers, and applications programs. Each program tape must be marked or labelled so that it can be easily located and identified. Many convenient devices are available for filing and storing tapes and computer users are advised to make maximum use of these units to preserve the investments of time and money that were made in preparing the tapes. The most popular storage devices for paper tape consist of partitioned plastic boxes. Paper boxes are also frequently used for storage and mailing purposes.



PAPER TAPE READERS

MANUFACTURER	MODEL	MAX. READING SPEED	MAX. ASYNC. SPEED	SENSING ELEMENT	TRACKS OR CHANNELS	TAPE MOVEMENT	BLOCK OR LINE READER	APPROX. PRICE	COMMENTS
BURROUGHS	B141	1000 char/sec	—	—	5,6,7, or 8	Bi-directional	—	—	Compatible with most data collection and transmission devices
CALIFORNIA TECHNICAL INDUSTRIES	171	15 blocks/sec	—	Pin contacts	8	Uni-directional	Block (10 lines)	—	Includes verifier panel
	220B	55 char/sec	40 char/sec	Pin contacts	5,6,7, or 8	Uni-directional	Line	—	
CHALCO ENGRG.	SBR-642	10 blocks/sec	3.5 blocks/sec	Pin contacts	8	Bi-directional	Block (16 lines)	\$2490	Price includes tape handler
	701	20 blocks/sec	2.5 blocks/sec	Pin contacts	8	Bi-directional	Block (24 lines)	\$4000	Price includes tape handler
	501	550 char/sec or 35 blocks/sec	150 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line or block (8 lines)	\$4000	Reads blocks or lines
DALMO VICTOR	333	10 blocks/sec	—	Photocells	—	—	Block (10 lines)	—	Includes verifier panel
DIGITRONICS	2500	300 char/sec	300 char/sec	Photocells	5,6,7, or 8	Uni-directional	Line	\$780	Various options available
	B2500	300 char/sec	300 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line	\$1103	Various options available
	3000	700 char/sec	700 char/sec	Photocells	5,6,7, or 8	Uni-directional	Line	\$1512	Various options available
	B3000	700 char/sec	700 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line	\$1662	Various options available
	5000	—	—	Photocells	5,6,7, or 8	Bi-directional	Block (20 lines)	—	Block reader memory module
ELECTRONIC ENGRG.	PR-2105	12 blocks/sec	12 blocks/sec	Photocells	8	Uni-directional	Block (5 lines)	\$1700	Also available in other block sizes
	TP-4105	10 blocks/sec	10 blocks/sec	Pin contacts	8	Uni-directional	Block (5 lines)	\$1000	Bi-directional models available
	3000	200 char/sec	—	Photocells	—	—	Line	\$4000	Militarized
FERRANTI ELECTRIC	260	46 char/sec	40 char/sec	Photocells	8	Uni-directional	Line	—	Militarized
	196D	300 char/sec	285 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line	\$4400	
	196E	400 char/sec	380 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line	\$4400	
	422	600 char/sec	400 char/sec	Photocells	—	Bi-directional	Line	\$7400	Militarized
	425R	600 char/sec	400 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line	\$2475	Built-in tester
	425D	600 char/sec	400 char/sec	Photocells	5,6,7, or 8	Bi-directional	Line	\$2425	Desk-top unit
G.E. PRINTER-READER SECTION	PTR-80/81	500 char/sec	200 char/sec	Photocells	5,6,7, or 8	Uni and Bi-direct.	Line	\$1385	Reflected light reading
	PTR-90/91	1000 char/sec	225 char/sec	Photocells	5,6,7, or 8	Uni and Bi-direct.	Line	\$1745	Reflected light reading
	PTR80C	200 char/sec	135 char/sec	Photocells	5,6,7, or 8	Uni-directional	Line	—	Reflected light reading

PAPER TAPE READERS (Cont'd.)

MANUFACTURER	MODEL	MAX. READING SPEED	MAX. ASYNC. SPEED	SENSING ELEMENT	TRACKS OR CHANNELS	TAPE MOVEMENT	BLOCK OR LINE READER	APPROX. PRICE	COMMENTS
HONEYWELL EDP	209	600 char/sec	—	Photocells	5,6,7, or 8	Bi-directional	Line	—	Special control unit for on-line
INVAC	R-110	—	35 char/sec	Photocells	5,6,7, or 8	Uni-directional	Line	\$495	
	R-125	—	200 char/sec	Photocells	5,6,7, or 8	Uni-directional	Line	\$750	
NAVIGATION COMPUTER	1280	—	30 char/sec	Pin contacts	5,6,7, or 8	Uni-directional	Line	—	Without drive or advance circuits
	1291	30 char/sec	30 char/sec	Pin contacts	8	Bi-directional *	Line	—	Self-contained, desk top
OHR-TRONICS	119	30 char/sec	—	Star-wheel	5,6,7, or 8	Bi-directional	Line	—	Rack-mounted
	153	30 char/sec	—	Star-wheel	5,6,7, or 8	Bi-directional	Line	\$345	Panel-mounted reading mechanism
POTTER INSTRUMENT	PTR-500	500 char/sec	100 char/sec	Photocells	5, 7, or 8	Bi-directional	Line	—	
	PSR-200	200 char/sec	—	Photocells	8	Bi-directional	Line	—	Militarized
	3277	200 char/sec	—	Photocells	8	Bi-directional	Line	—	Militarized
	PT-5000	500 char/sec	—	Photocells	8	Bi-directional	Line	—	Militarized; dual-speed
	PE-1000	1000 char/sec	—	Dielectric	5,6,7, or 8	Bi-directional	Line	\$4000	
REMEX	RR-702/1002	700 char/sec	140 char/sec	Photocells	5,7, or 8	Uni and Bi-direct	Line	—	
	RR-5000	1000 char/sec	200 char/sec	Photocells	5,7, or 8	Uni and Bi-direct	Line	—	
	RR-102/302	300 char/sec	100 char/sec	Photocells	5,7, or 8	Uni and Bi-direct	Line	—	
ROYTRON	550	50 char/sec	30 char/sec	Pin contacts	5,6,7, or 8	Bi-directional	Line	\$285	Price does not include housing, timing or mechanical drive. Complete systems available
	200	20 char/sec	20 char/sec	Pin contacts	5,6,7, or 8	Uni-directional	Line	\$310	
	750	75 char/sec	45 char/sec	Pin contacts	5,6,7, or 8	Bi-directional	Line	\$405	
SOROBAN	FFR	350 char/sec	300 char/sec	Fluid-flow	5,6,7, or 8	Uni-directional	Line	\$3950	Complete with power supplies
	FR-2	60 char/sec	60 char/sec	Pin contacts	5,6,7, or 8	Bi-directional	Line	\$1750	
	FR-4015	20 char/sec	—	Pin contacts	5,6,7, or 8	Uni-directional	Line	\$740	Read head and solenoid drive
TALLY	424	—	60 char/sec	Star-wheel	5,6,7, or 8	Bi-directional	Line	\$635	Panel-mounted
	464	—	120 char/sec	Star-wheel	5,6,7, or 8	Bi-directional	Line	\$745	Panel-mounted
	625	—	25 char/sec	Star-wheel	5,6,7, or 8	Uni-directional	Line	\$325	Panel-mounted
	824	—	60 char/sec	Star-wheel	16	Bi-directional	Line	\$1430	Panel-mounted
TELETYPE	CX-1050	105 char/sec	—	Pin contacts	5,6,7, or 8	Uni-directional	Line	—	Used in communications
WANG LABS	TR	—	10 blocks/sec	Brushes	5,6,7, or 8	Uni-directional	Block	\$1200	Available in 6 to 32 lines/block

PAPER TAPE PUNCHES

MANUFACTURER	MODEL	MAX. PUNCHING SPEED (char/sec)	TRACKS OR CHANNELS	PARITY ERROR SENSING	END OF TAPE SENSING	TAPE SUPPLY LEVEL SENSING	PACKAGING STYLES	APPROX. PRICE	COMMENTS
BURROUGHS	B341	100	5,6,7, or 8	—	—	Yes	Console		Complete buffered operation
G. E. PRINTER-READER SECTION	ETR-7	600	5,6,7, or 8	Yes	Yes	No	Rack, console		Electrostatic recorder for reflected-light tape reader
HONEYWELL EDP	210	120	5,6,7, or 8	Yes	Yes	Yes	Console		Special control unit for read-punch operations
INVAC	P-135	35	5,6,7, or 8	No	Yes	Yes	Desk-top, console, rack	\$640	Price includes core suppression network and circuitry for controlling operation of sprocket, transport, and bail solenoids
NCR	EM-B1	120	5,7,8	No	Yes	No	Rack, console		Punching mechanism only
	EM-B2	120	5,7,8	No	Yes	Yes	Rack, console		Punching mechanism plus tape transport
NAVIGATION COMPUTER	1010	12	5,6,7, or 8	Optional	Yes	Visual	Desk-top	\$1500	Characters printed on tape edge; keyboard included
OHR-TRONICS	110	30	5,6,7, or 8	Yes	Yes	Optional	Rack, desk-top		Senses parity before punching and can inhibit punching
POTTER INSTR.	PE-1500	150	5,6,7, or 8	No	Optional	Optional	Desk-top, rack	\$1930	Separate electronic unit and power supplies are available
ROYTRON	500	50	5,6,7, or 8	Optional	Optional	Optional	desk-top, console, rack	\$325	Mechanical drive and timing not included
	700	75	5,6,7, or 8	Optional	Optional	Optional	desk-top console, rack	\$450	in price quoted here but models with
	200	20	5,6,7, or 8	Optional	Optional	Optional	Rack, desk-top, console	\$350	complete drive and logic are available. Verify-duplicate system and tape re-generation system also available.
SOROBAN	LP-2	150	5,6,7, or 8	Optional	Yes	Yes	desk-top, console, rack	\$3200	Also available as punch heads only
	GP-2	300	5,6,7, or 8	Optional	Yes	Yes	desk-top, console, rack	\$7900	
	PT-2	100	5,6,7, or 8	Optional	Yes	Yes	Console	\$14,000	
TALLY	P-30	30	5,6,7, or 8	Optional	No	Yes	Rack, console	\$575	Price includes feed and take-up reel on panel mount
	P-120	120	5,6,7, or 8	Optional	Optional	Optional	Rack	\$1350	Price includes feed and take-up reel on panel mount
	420	60	5,6,7, or 8	No	Optional	Optional	Rack	\$1200	Price includes feed reel on panel mount
	P-150	150	5,6,7, or 8	Yes	Yes	Optional	Rack	\$1850	Reels not included in price but available in P-150A
TELETYPE	DRPE	200	5,6,7, or 8	No	No	Yes	Rack, desk-top	\$850	Feed reel included, features tuned reed punching
	BRPE	110	5,6,7, or 8	No	No	Yes	Rack, desk-top	\$725	Feed reel included
	35 ROTR	10	810	No	No	Yes	desk-top, console, rack	\$900	
	28 LPR	10	5	No	No	Yes	Desk-top, rack	\$935	
	28 LARP	20	5,6,7, or 8	No	No	Yes	Desk-top	\$500	Parallel input only

INPUT TYPEWRITERS AND KEYBOARDS

Manual input to a computer or other data processing system is usually indirect, simply because the human user and the machine operate at vastly different rates. Where large quantities of data are involved, it is more efficient and economical for the slow-rate operator to transfer the input information, off-line, onto punched cards, paper tape, or magnetic tape, which the system can then absorb at its own rapid rate. However, some means of direct manual input is still a necessity in most applications. It may take the dynamic form of real-time query or entry of transient information, or the static form of setting up constants and operational parameters. The dynamic form of input is generally via a keyboard unit which may, or may not, also produce hard copy for operator use.

An input typewriter is a keyboard unit which produces hard copy in ordinary typewriter fashion, but at the same time generates electrical signals that are fed directly into an EDP system. Computer input typewriters are essentially conventional type-

writers and, therefore, introduce the usual high-current surges and gross electromechanical motions associated with these devices. The coded electrical outputs are added on, and the output signals tend to be contaminated with noise. Therefore, the user usually provides electrical buffering for the signals to the computer. Currently-available input typewriters are summarized in the product summary charts following this discussion.

In recent years there has been an increasing number of "keyboard-only" units for applications which do not require printed copy along with the input signals. These units, free of the requirement of driving relatively-massive mechanical printing elements, are simpler, smaller, and generate less electrical noise than typical input typewriters. Many manufacturers of pushbutton switches frequently build such switches into special-purpose keyboard control panels. The following charts list only complete keyboard units designed for rapid, manual operation in the manner of a typewriter or adding machine.

INPUT TYPEWRITERS

MANUFACTURER	MODEL	CHASSIS	TECHNIQUE	CODE	RATE	COMMENTS
CONN. TECHNICAL		Underwood	Electromechanical	Direct	9.3 char/sec	
DURA BUS. MACHINES	MACH 10	Selectric	Electromechanical	8 bits	15.4 char/sec	I/O via paper tape
FRIDEN	2303		Electromechanical	8 bits	145 words/min	I/O via paper tape
INVAC	TTR100	RemRand	Photoelectric	8 bits	10 char/sec	
	TTR200	Selectric	Photoelectric	8 bits	15.5 char/sec	
SCM	311		Photoelectric	6 bits	24-40 char/sec	
SOROBAN	Computeriter	IBM	Electromechanical	8 bits	10 char/sec	

INPUT KEYBOARDS

MANUFACTURER	MODEL	TECHNIQUE	KEYS	CODE	COMMENTS
BURROUGHS	410	Electromechanical	13, 16	Direct	
CONN. TECHNICAL	KB-100	Electromechanical	70	8 bits	High-speed unit
	KB-200	Electromechanical	50	6 bits	
INVAC	Series 200	Photoelectric	Unlimited	Up to 14 bits	Built-in universal encoding
	PK-144	Photoelectric	46	8 bits	Other codes available
	PK-164	Photoelectric	64	8 bits	Other codes available
NAVCOR	1050	Electronic	50	8 bits	Pulse, buffered timing outputs
	1050N	Electronic	16	8 bits	Pulse, buffered timing outputs
SOROBAN	FK	Electromechanical	Up to 64	8 bits	Up to 16 bits also available
TELETYPE		Electromechanical	52	Direct	Special purpose keys
ULTRONIC SYSTEMS	500	Electromechanical	Unlimited	5 bits	Visual display
	600	Electromechanical	Unlimited	Unlimited	Visual display

INTERNAL MEMORY SYSTEMS

The high-speed, random access memory is rapidly becoming the most important single element of an internal computing system. The newer computer organizations which are now evolving are placing greater demands on the memories, and are creating a dramatic change in the economic balance between the computer central processor and the main internal memory. Where in the past a computer system consisted of one data processor and one memory, the newer modular systems may contain 2 or 3 processors and up to 8 or 16 separate memories. Along with this demand for increased numbers of memories, there has also been a demand for increased capacity and speed in the individual memory. Typical memory capacities have increased from 4,096 to 16,384 words, and word lengths have increased from 24 and 36 bits to 48 and 72 bits. Cycle times have decreased from the 10 microseconds common in the late 50's to the 1 microsecond and even less that are considered relatively standard today. These changes and improvements in memories have been a result of the pressure brought to bear by the computer systems people and of the improved materials and design techniques which have become available in the last few years.

Unfortunately, for the computer systems man, memories have remained somewhat of a black art; the rather limited number of people skilled in the art have little time to write tutorial papers of the type needed by the computer systems man because of the pressure of their schedules. This discussion is an attempt to provide, for the systems man, a guide to the selection of a memory system. Included are discussions of all the aspects of a memory with which he needs to be familiar to select and specify a memory properly for any application at a minimum cost. The discussion is concluded with a tabulation of the characteristics of the product memories which are commercially available.

General Organizational Characteristics

The most important selection characteristics of an internal memory are organization, capacity, and timing. The ferrite core memories which are available today (or which will be available in the foreseeable future) fall into one of three basic organizations:

- 3D, or coincident-current;
- $2\frac{1}{2}$ D, 3-wire—in smaller and faster main memories (10^6 bits);
- $2\frac{1}{2}$ D, 2-wire—in the larger, slower bulk core memories (5×10^6 bits).

The 2D or linear select organization has been and is continuing to be used in core systems but only in a few special memories which are not available as standard products.

A new form of memory which is starting to gain prominence is the thin film memory, which, at the present time is not generally available on the market, but is being manufactured by several computer manufacturers for use on their own systems. It is only a matter of time before they will be available as product memories. At the present time thin film memories fall into two general groups: the planar film memories and the cylindrical film (plated wire) memories. Both types are organized as 2D (linear select) memories. The one exception to this is a $2\frac{1}{2}$ D plated wire memory which has been described by one computer company. Thin film memories have cycle times ranging from 0.5 microsecond to under 100 microseconds and it is clear that for cycle times less than 500 nanoseconds, they will dominate the field. In the range from 500 nanoseconds up in cycle time, the choice will be based on economic considerations and only time will determine whether thin film or core will be the more widely used.

The details of the different core memory, organizations, such as 3D and $2\frac{1}{2}$ D, have been described in considerable detail in magazine articles (particularly in COMPUTER DESIGN) and will not be repeated here. It is important, however, for the systems engineer to understand the effect of the organization on the system performance and cost. The cost, performance, and reliability of a memory system are very much a function of the way the system is organized. "Organization" means not only the logical structure (3D or $2\frac{1}{2}$ D) but also the size and logical dimensions of the basic homogeneous memory module (BOM). The term "BOM" for "Basic Operating Memory" has been recently coined by the engineers at IBM Poughkeepsie, and will be used here. For a given speed and logic structure, there is some maximum module size which should not be exceeded or the delays and noise will begin to accumulate and the reliability of the system will suffer. For any requirement, however, the BOM should be as large as possible to achieve the minimum per-bit cost.

The way the BOM is organized depends on a number of factors, not the least of which are the personal prejudices of the designer. It is possible to arrive at a given memory system design through the use of any of a number of different BOM's. To illustrate this, let us consider the example of a memory system with a specified capacity of 16,384 words, 72 bits, and a cycle time of 1 microsecond.

- **DESIGN APPROACH #1:** The BOM is built around a 3D, 4-wire core stack using 24 mil cores. The maximum size homogeneous stack to achieve the 1 microsecond cycle time is $128 \times 128 \times 18$ ($16,384 \times 18$). Four of these modules are used to make up the full 72 bits. Each module is electronically independent of the others; the only common points are the address register and the timing and control logic.

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■ **DESIGN APPROACH #2:** The BOM is built around a 3D, 4-wire, 24 mil core stack which is logically $64 \times 64 \times 72$ (4096×72). With this design, four modules are required to make up the full 16,384-word capacity, and the modules would share some common information control circuitry such as the information register and sense amplifiers.

■ **DESIGN APPROACH #3:** The BOM is built around a $2\frac{1}{2}D$, 3-wire, 30 mil, core stack which is $32 \times 256 \times 2 \times 18$ ($16,384 \times 18$). Four of these modules are required.

All three of the organizations just outlined are capable of achieving the cycle time needed with adequate reliability. Neither of the three has any obvious cost advantage. Cost advantage is generally much more a function of the cleverness of the design engineer and the efficiency of the manufacturer. This is not true for all memory requirements.

In general, when a memory with many short words is needed (for example $16K \times 7$), the $2\frac{1}{2}D$, 3-wire organization has the cost advantage; when a smaller number of long words is required (for example $4K \times 48$), the 3D, 4-wire structure is better.

The system designer has still another degree of freedom in selecting the most economical organization for a requirement. It is often desirable to have a memory word length which is some integral multiple of the word length needed by the computer. For example, if the requirement is for 8,192 words of 17 bits, it might be cheaper to make a memory which has 4096 words of 34 bits and then address-select one or the other group of 17 bits from the information register. The other group would be automatically regenerated. Occasionally the mode of operation will have an effect on the organization of the memory. The normal mode is full cycle, read-regenerate or clear-write. For some applications, it is desirable to operate either split-cycle, read-pause-write, or half-cycle, read-only through many or all addresses and then write-only at a later time. The main virtue of these modes is that they can result in significant increases (up to X2) in effective memory speed in some special applications. However, they impose some severe restrictions on the memory drive circuitry; the effect of these restrictions is a function of the design and circuitry of the memory, but as a general rule these modes of operation should be avoided.

Where speed is the primary factor, the $2\frac{1}{2}D$, 3-wire design is the obvious choice. Several companies have achieved 500 nanoseconds cycle time in $2\frac{1}{2}D$ systems with no great difficulty. This can be done with a 3D system only with considerable difficulty.

When a specification for a memory requirement is being created, it should be made as non-restrictive as possible, so as to allow the memory suppliers to pick the most efficient and economical organization for the application.

Timing

There are several aspects of the timing of a memory which are important for the system designer to consider. The first and most familiar design feature is the cycle time. The term "cycle time"

is often misunderstood due to fundamental differences in definitions. The generally accepted definition of cycle time is as follows. "The period of time which is required for a memory to go through a complete read-write cycle and be prepared to begin the next cycle. The starting point is that instant when the input address and information and control lines are stable and a start pulse tells the memory to GO. The end of a cycle is that instant when the memory is prepared to accept new address information and control data and a new GO pulse."

The read access time is also an important memory characteristic. This can be defined as follows. "The period of time which is required for the information output lines from a memory to become stable after the read portion of a read memory cycle. The starting point is that instant when the input lines are stable and a GO pulse is transmitted to the memory. The end of the read access period is that time when all information output lines are guaranteed to have settled to their stable states with the new information."

It is important that all timing be defined at the memory input-output connectors. In faster memories it is possible for the communication cables to have a delay which is a significant portion of the memory cycle time. It is not uncommon to have delays approaching 100 nanoseconds in cables. Considering transmission in both directions, this delay can be 20% of the memory cycle time for a 1-microsecond memory.

There is another aspect of memory timing of which system designers should be aware; that is, memories are almost universally asynchronous. This means that once they have received the GO pulse, they go their merry way, creating their own timing points without regard to the system clock or timing. The most common means of controlling the timing of a memory is by means of a delay line through single-shot multivibrators as in the case of a split-memory cycle. In this case, the computer triggers the read and write portions of the cycle separately. Split cycles are discussed further in the following paragraphs.

System Characteristics and Circuit Considerations

In addition to the organizational characteristics, there are other system characteristics which a memory specifier must keep in mind. Two of these are modularity and duty factor.

■ **Modularity**—It is often desirable to provide a memory whose capacity is modular, that is, a basic system is provided with several optional capacities. Also, it is often desirable (or necessary) to change the memory capacity in the field at a minimum cost to the customer, and this requirement places definite constraints on the design and organization of the memory. This factor should be included in the initial system specification.

■ **Duty Factor**—The duty factor of accesses to any given address is an important factor in the design of a memory—not from a circuit standpoint, since the nature of a memory dictates that all circuits must

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operate at 100% duty factor, but from the standpoint of the core itself. Continuous access to one address can cause excessive heating in the cores and a resultant loss of margins and, therefore, reliability. It is highly improbable that any computer would require continuous access to one address, or even that a duty factor as high as 50% would ever exist averaged over a 100-millisecond interval, except in some synthetic test mode. Duty factor limitations should be very carefully thought out before being included in a memory system specification.

In all of the product memories on the market, the manufacturers have interface circuits which will convert the customer's logic levels to those required by the internal logic of the memory. There are, however, some advantages to having memory logic levels which match those of the computer, since the interface circuit is eliminated along with the delay and decrease in reliability which would result from its inclusion. As in computer systems, there has been a transition from germanium PNP to silicon NPN to integrated circuits. In order to simplify the parts stocking and maintenance problems, it is very desirable to have logic circuits in the memory which use logic devices (transistors or IC's) which are the same or similar to those used in the associated computer.

In making a final decision on which memory to select, the user should take a careful look at the circuit design of the memory. For review purposes, the circuits can generally be lumped into three groups and the points to be looked for are different in each group.

- For the logic circuits, the problem is simply one of adequate worst-case design to allow for drift of components.
- In the driving circuits, the user should look for adequate dissipation ratings of the high current components which determine the drive currents; short and long term drift of these components can result in a poor reliability and a high error rate or can necessitate high maintenance.
- In the sensing circuits, the factors to be looked for are uniform characteristics and long term stability.

Despite the need for a careful review of the circuitry, it is almost impossible to write a meaningful specification which can cover the circuits. The best that can be done is a clause which requires that the memory manufacturer submit any changes to the user for review after the design is accepted.

Environmental Characteristics

Ferrite cores are temperature-sensitive devices; increases in temperature cause the optimum drive current to decrease, with a temperature coefficient of current in the neighborhood of $-0.5\%/\text{C}$. If the memory is required to operate over a range of temperature greater than (for example) 5 C , some method of temperature compensation must be incorporated in the design. The usual method of achieving

the compensation is to place a temperature sensor in the air stream of the core stack and use it to change the magnitude of the drive currents, by varying a reference power supply.

An alternative to the temperature sensitive core is the use of Lithium cores which are much less sensitive to temperature. They do, however, require higher drive currents and thus force compromises in the system design. A typical temperature range for a commercial system is 15°C to 55°C . Where extremely wide temperature ranges are required, as in some military systems (-50°C to $+125^\circ\text{C}$, for example), it is necessary to use both temperature stable cores and temperature compensation.

In a previous section, the effect of duty factor on a single address was discussed. In addition to this, there is another duty factor consideration which must be considered on some memories. In a 1 microsecond, 3D memory there is a significant amount of power dissipated in the inhibit line. High duty factors when writing "ZEROS" in a given inhibit line segment can cause a temperature rise over a period of several seconds which can be as high as 10°C if the stack is not properly cooled. This rise can be uneven and result in a temperature differential through the stack, materially reducing the system operating margins. This characteristic can be guarded against by requiring, as part of the approval specification, operating tests which simulate the condition.

The other environmental characteristics—shock, vibration, humidity—are not normally a problem in commercial equipment. Generally, commercial class memories are not tested or specified for shock and vibration in operation. Severe shock and vibration can, however, be encountered in shipping, so the memory buyer should assure himself that the manufacturer has properly protected the memory, especially the core stack, from the hazards of shipping.

The standard humidity range for commercial equipment is 10% to 90% R.H. operating and 5% to 95% storage. In some tropical regions, higher humidity is encountered. When conditions beyond normal ranges are encountered, this should be called out on the specification. Before a system is accepted, the buyer should assure himself that the manufacturer has truly considered these special conditions and allowed for them in the design.

In military memories, a whole new set of environmental problems is encountered. These should be handled on an individual basis and controlled by properly-written mil specs.

Power and Packaging

The power portion of a digital system is often neglected and left as an afterthought. In writing a system specification, several factors relating to power must be considered, and the complete characteristics of the available power must be known and called out.

The memory user must first determine what primary power is available; 60 Hz power is standard in North America, but in Europe 50 Hz is generally used. Available voltages vary widely. Typical ones are: 115V 1phase; 230V, 2 wire, 1phase; 230V, 3 wire, 1phase; 208V, 3phase delta; 208V, 3phase, Wye. The use of three-phase power allows some economies in the power supply design, but most

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office buildings do not have readily available three-phase connections. The available power must be investigated and the trade-off in cost between power supply and power installations should be considered.

The voltage and frequency regulations are also important. Normal voltage regulation is $\pm 10\%$ but in some remote locations, worse can be encountered. Frequency is thought to be an invariant property, and, in fact, it is in a well-run power company. However, in remote locations this is not always true, and in extreme cases, 1- or 2-cycle variations can be encountered. Since resonant-type regulating transformers are frequency-sensitive, the line frequency can affect the internal voltage to the memory circuits. Often power line dropouts are encountered, that is, several cycles are abruptly missing on the line. This generally results from transformer switching operations by the power company. This puts rather severe constraints on the filtering system to carry the load for this interval.

There are several characteristics of the DC power supplies about which the memory buyer should be concerned. It is desirable for the individual supplies to have sensing of both over- and under-voltage. When either condition is encountered, an orderly power shutdown should be initiated. The actual power consumption is almost never a problem in a commercial memory system. In a military system, however, it is often an all-important factor. In such cases, both the peak operating power and standby power might be important and should be called out on the specification.

The method of dissipating the internally-generated power is a factor of considerable interest to the memory buyer. Although not normally an item which is specified (except in some military applications) it should be considered before a purchase is made to make sure that the memory cooling is compatible with that of the rest of the system. Factors such as temperature rise of the coolant are also not specified parameters but are indicative of the adequacy of the cooling and the conservatism of the design.

The system packaging is an area in which the customer should be interested enough to convince himself that it is both reliable and properly maintainable. The specification should not be restrictive other than to call out maximum dimensions and mounting hardware.

Maintenance

The proper maintenance of a memory is an extremely important factor. Memories are basically analog systems and as such are subject to more variations than a truly digital system.

It is possible to design a memory with fixed operating points and no operating adjustments. However, this is a very unwise course. It is desirable to have several operating adjustments on such parameters as drive current, noise clipping threshold, and strobe time. These adjustments allow the manufacturer to adjust the system initially to the optimum operating point, and assist the field engineer in performing preventative maintenance. They thus help insure a long, error-free life for the system. The operating adjustments must be accompanied by some means of exercising the memory through a series of worst-case-pattern tests. These tests are best accomplished with an

exerciser built into the memory. There are two design philosophies for built-in exercisers for memories. One is to imbed the exerciser into the memory; with this approach, the exerciser utilizes the logic and registers of the memory as part of the logic for the exerciser. This approach only requires the addition of a few circuits over what is already there—a pattern generator, an error detector-comparator, address register count logic, and a few miscellaneous control circuits. Its disadvantage is that it does not check the communication links with the computer.

The other philosophy for an exerciser is to make it an independent unit which takes the place of the computer. This type of exerciser must have registers and other logic circuits which duplicate those in the memory. The separate exerciser has the advantage that it can be shared by more than one memory in a multi-memory system.

The choice of exerciser will generally be dictated by the philosophy of the manufacturer selected to supply memory. If the manufacturer offers both, the choice should be based on system economics since neither exerciser has a clear-cut superiority over the other.

The exerciser can also be implemented by programming on the computer if it is a system which has more than one memory. Whatever the implementation, the exerciser should provide a facility for setting in the worst-case pattern and several less severe patterns, including all "1" and all "0". It should have the ability to cycle through all addresses, searching for errors, as the operating adjustments are varied. If these error points are plotted on a graph which has two of the operating variables as axes and a third as a fixed parameter, a family of "shmoo" curves is the result. The "Shmoo" plot is a valuable tool for initially setting up a memory and for maintaining it in the field.

To facilitate maintenance, several other features are often included. Indicators for all flip-flops are very desirable; in fact, trouble-shooting can be very awkward without them. The indicators are often accompanied by switches for manual set or clear of the flip-flops. Care should be taken that the maintenance facility is not too complicated. If there are too many operating adjustments, using them is an almost impossible task. More than 3 or 4 have no real value and, in fact, are symptomatic of a poor design (for example, one pot on each sense amplifier). The functions and controls of the maintenance panel should be carefully human-engineered. If performing the tests is too inconvenient or time consuming, the field and test engineers will tend to not use the facilities and the memory will end up not being properly maintained or adjusted.

Miscellaneous Features

In addition to the characteristics already discussed, there are a number of points which must be considered by the user and covered in the specification. These will be listed and discussed briefly.

- Communication and control lines to and from the memory must be clearly called out. In some situations, special functions may be needed such as:

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Address Register Clear
Information Register Clear
All Registers Clear
End-of-Cycle Indication
Read Access Complete

- The general handling of the set and clear of registers; whether to clear all registers automatically and control flip-flops at the end of a cycle, or to set the registers directly to the new state.
- It is sometimes desirable to be able to increment the address register from a single control line, by making the register into a counter.
- Mode of data transfer; the data and control can be transferred either single-ended or double-ended (single or double "rail"), by transmitting only the "true" of the data, or both the "true" and "complement" of the data.
- Parity generation and checking are often needed and are generally available but the buyer should be aware of its cost. It not only adds an extra bit to the memory (along with the logic circuits) but often necessitates an awkward stack layout. For example, if a 4096 by 16 bit memory is required, the stack fits nicely onto four planes of 128 x 128 cores, each segmented to 64 x 64 sections. The addition of a parity bit requires an extra plane with only 1 segment included. Parity is often essential to insure system reliability but it may be that its cost is out of proportion to its functional value in some applications. The value of its inclusion should be carefully considered.
- Memory retention on power down, a feature which is often needed on a memory,

is the ability of the memory to retain its data stored when there is a controlled power off. To achieve this, the various power supplies in the memory must be turned off and on in the proper sequence. On the off cycle, this feature generally is accomplished by having the power voltages which actually generate the drive currents separated from the logic voltages. These voltages are turned off first and on last. Following these voltages are the special amplifier voltages and then the logic voltages. The important thing is that no spurious current pulses should be generated during power on and off cycles.

In connection with this feature, one thing should be clearly understood; that is, that when there is an unscheduled power down which is caused by some fault (either over- or under-voltage), memory retention cannot be guaranteed. It may very well be achieved but you never know what triggered the power down. It could have been an under-voltage of the bias supply which keeps current drivers off.

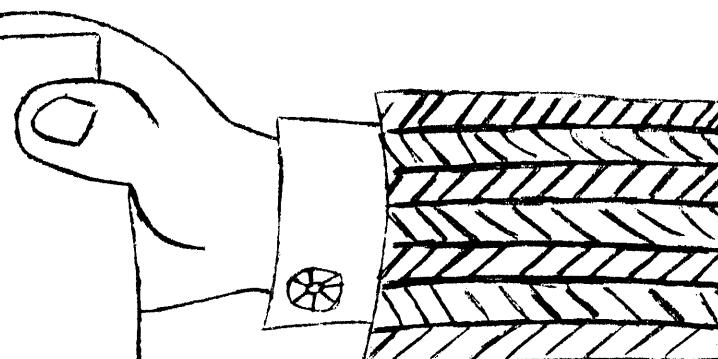
Summary

The important thing for the specifier (memory buyer) to keep in mind is to call out all of those parameters which directly affect his system and the performance of the memory within the system. He should, however, be very careful not to tell the memory designer how to design his memory but should instead convince himself that the designer has done an adequate job of creating a reliable design.

The specification should contain two classes of items. The first are those items which tend to be inherent in the design and are subject to testing only once on the "type" approval tests. The other class of parameter is that which is subject to manufacturing variation and should be subjected to testing on all units produced. Operating margins (shmoos) fall into this class.

memo:

*See Product Category 10
in the Product Directory
for complete names and addresses
of Internal Memory Systems Manufacturers -*



CORE MEMORY SYSTEMS

MANUFACTURER	AMPEX		BURROUGHS	DECISION CONTROL		
MODEL	RS	RF	BFC-600	STD. VERSASTORE	M. F. VERSASTORE	"NCR" BUFFER
TIMING Cycle time (usec.)	1	1.5	0.6	1.5	1.7	3
Read access time (usec.)	0.4	0.5	0.3	0.7	0.6	0.9
BASIC STRUCTURE	3D-4 wire	3D-4 wire	2 1/2D-3 wire	3D-4 wire	3D-4 wire	3D-4 wire
BOM* CAPACITY						
Minimum words	4096	512	4096	256	4096	256
Maximum word	4096	4096	8192	4096	4096	4096
Minimum bits/word	8	4	10	4	4	6
Maximum bits/word	40	18	20	24	36	18
Bits/word increment	4	2	1	2	2	2
MODES OF OPERATION						
Full cycle	Yes	Yes	Yes	Yes	Yes	Yes
Split cycle	Yes	Yes	Yes	Yes	Yes	No
Half cycle	No	Yes	No	Yes	Yes	Yes
DATA RETENTION	Yes	Yes		Yes	Yes	Yes
ADDRESS INCREMENTING BY ADDRESS REG. COUNTER	No	Yes	Yes	Yes	Yes	No
DRIVE CONFIGURATIONS						
Diode-transformer	X					
Diode-balun	X		X	X	X	
2 diode/line direct		X				X
4 diode/line direct						
SEPARATE REGISTER CLEAR	Yes	Yes	Yes	Yes	Yes	No
PARITY GEN. AND CHECK LOGIC	Yes	No	Yes	No	No	No
DATA TRANSFER MODE	SR**	SR**	SR & DR**	SR**	SR**	SR & DR**
LOGIC CIRCUITRY	Discrete	IC	IC	IC	IC	IC
ENVIRONMENTAL FACTORS						
Operating temp. (°C)	10 to 40	0 to 50	15 to 40	10 to 45	10 to 45	10 to 50
Shock and vibration	Comm.	Comm.	Comm.	Comm.	Comm.	Comm.
Temp. compensating currents	Yes	Yes	Yes	Yes	Yes	Yes
Wide temp. cores	Yes	Yes	No	No	No	No
MAINTAINANCE AIDS						
Internal or external exerciser	External	External	External	External	Either	None
Indicator lights on flip-flops	No	No	Yes	Yes	Yes	No
Flip-flop set/clear controls	Yes	No	No	No	No	No
Shmoo plotting	Yes	Yes	—	Yes	Yes	—
Sense threshold adjustment	Yes	Yes	Yes	Yes	Yes	Yes
Inhibit current adjustment	Yes	No	No	Yes	Yes	Yes
Drive current adjustment	Yes	Yes	Yes	Yes	Yes	Yes

* Refers to "Basic Operating Module" (see preceding text)

** SR = single rail; DR = double rail

CORE MEMORY SYSTEMS (Cont'd.)

MANUFACTURER	DI/AN CONTROLS		ELECTRONIC MEMORIES			FABRI-TEK
MODEL	SA	RSA-MIL	SEMS-5	NANO. 900	NANO. 650	MT
TIMING Cycle time (usec.)	10	1.75	2	0.9	0.65	4.0
Read access time (usec.)	3	0.75	0.7	0.35	0.30	2.0
BASIC STRUCTURE	3D-4 wire	3D-4 wire	3D-3 wire	2 1/2D-3 wire	2 1/2D-3 wire	2 1/2D-2 wire
BOM* CAPACITY Minimum words	36	256	256	4096	4096	65,536
Maximum words	2346	4096	4096	16,384	16,384	262,144
Minimum bits/word	2	4	4	8	8	20
Maximum bits/word	16	28	32	84	84	80
Bits/word increment	—	4	2	Variable	Variable	1
MODES OF OPERATION Full cycle	Yes	Yes	Yes	Yes	Yes	Yes
Split cycle	Yes	Yes	Yes	Yes	Yes	No
Half cycle	Yes	No	Yes	Yes	Yes	No
DATA RETENTION	Yes	Yes	Yes	Yes	Yes	Yes
ADDRESS INCREMENTING BY ADDRESS REG. COUNTER	No	Yes	No	No	No	Yes
DRIVE CONFIGURATIONS Diode-transformer		X				X
Diode-balun						X
2 diode/line direct			X	X	X	
4 diode/line direct						
SEPARATE REGISTER CLEAR	Yes	Yes	No	Yes	Yes	Yes
PARITY GEN. AND CHECK LOGIC	—	Yes	No	Yes	Yes	Yes
DATA TRANSFER MODE	SR & DR**	SR**	SR**	SR**	SR**	SR & DR**
LOGIC CIRCUITRY	Discrete	IC	IC	IC	IC	IC
ENVIRONMENTAL FACTORS Operating temp. (°C)	0 to 50	0 to 80	-55 to 85	0 to 45	0 to 45	60 to 90
Shock and vibration	Comm.	Mil.	Mil.	Comm.	Comm.	Comm.
Temp. compensating currents	—	No	Yes	Yes	Yes	Yes
Wide temp. cores	—	Yes	Yes	No	No	No
MAINTAINANCE AIDS Internal or external exerciser	External	External	External	Internal	Internal	Internal
Indicator lights on flip-flops	Yes	Yes	No	Yes	Yes	Yes
Flip-flop set/clear controls	Yes	No	No	No	No	Yes
Shmoo plotting	—	—	Yes	No	No	Yes
Sense threshold adjustment	No	No	No	No	No	Yes
Inhibit current adjustment	No	No	No	Yes	Yes	No
Drive current adjustment	No	No	No	Yes	Yes	Yes

* Refers to "Basic Operating Module" (see preceding text)

** SR = single rail; DR = double rail

CORE MEMORY SYSTEMS (Cont'd.)

MANUFACTURER	FABRI-TEK					FAIRCHILD	
MODEL	MSA2	MLA2	MMA2	MFA1	MD	MISER	PACER
TIMING							
Cycle time (usec.)	2	2.0	1.8	1.0	0.65	1.6	0.65
Read access time (usec.)	0.80	0.75	0.75	0.38	0.325	0.65	0.40
BASIC STRUCTURE	3D-4 wire	3D-4 wire	3D-4 wire	3D-4 wire	2-1/2D-3 wire	3D-4 wire	2-1/2D-3 wire
BOM* CAPACITY							
Minimum words	4096	64	2048	4096	4096	1024	2048
Maximum word	16,384	4096	4096	16,384	16,384	4096	8192
Minimum bits/word	16	4	6	2	2	8	16
Maximum bits/word	40	24	18	25	28	24	30
Bits/word increment	2	2	2	2	2	2	1
MODES OF OPERATION							
Full cycle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Split cycle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Half cycle	Yes	Yes	Yes	Yes	No	Yes	Yes
DATA RETENTION	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ADDRESS INCREMENTING BY ADDRESS REG. COUNTER	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DRIVE CONFIGURATIONS							
Diode-transformer	X			X			
Diode-balun	X			X	X		
2 diode/line direct						X	
4 diode/line direct	X	X	X		X		X
SEPARATE REGISTER CLEAR	Yes	Yes	—	Yes	Yes	Optional	Yes
PARITY GEN. AND CHECK LOGIC	Yes	No	No	Yes	Yes	No	Yes
DATA TRANSFER MODE	SR or DR**	SR & DR**	SR & DR**	SR or DR**	SR**	SR**	SR or DR**
LOGIC CIRCUITRY	Discrete	Discrete	IC	Discrete	Discrete	IC	IC
ENVIRONMENTAL FACTORS							
Operating temp. (°C)	0 to 50	10 to 45	10 to 45	10 to 40	10 to 40	0 to 55	10 to 45
Shock and vibration	Mil.	Mil.	Mil.	Mil.	Comm.	Comm.	Comm.
Temp. compensating currents	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wide temp. cores	No	No	No	No	Yes	No	No
MAINTAINANCE AIDS							
Internal or external exerciser	Internal	External	External	Internal	Optional	External	External
Indicator lights on flip-flops	Optional	Yes	No	Optional	Yes	Optional	Yes
Flip-flop set/clear controls	Optional	No	No	Optional	No	Optional	Yes
Shmoo plotting	Yes	—	Yes	Yes	—	Yes	Yes
Sense threshold adjustment	No	No	No	Yes	No	No	No
Inhibit current adjustment	Yes	Yes	Yes	Yes	No	Yes	Yes
Drive current adjustment	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* Refers to "Basic Operating Module" (see preceding text)

** SR = single rail; DR = double rail

CORE MEMORY SYSTEMS (Cont'd.)

MANUFACTURER	FERROXCUBE				HONEYWELL, 3C DIV.		
MODEL	FX-12	FX-14	FX-18	FX-22	TCM-32	ICM-40	ICM-47
TIMING							
Cycle time (usec.)	10	8.0	8	4	5	1.0	0.75
Read access time (usec.)	1.5	3.0	3.0	1.5	2.3	0.5	0.4
BASIC STRUCTURE	3D-4 Wire	3D-4 wire	3D-4 wire	3D-4 wire	3D-4 wire	2-1/2D-3 wire	2-1/2D-3 wire
BOM* CAPACITY							
Minimum words	128	512	8192	128	128	4096	4096
Maximum word	512	4096	16,384	512	4096	16,384	8192
Minimum bits/word	1	2	16	1	8	4	4
Maximum bits/word	8	32	32	8	36	26	28
Bits/word increment	1	2	2	1	2	2	2
MODES OF OPERATION							
Full cycle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Split cycle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Half cycle	Yes	Yes	Yes	Yes	Yes	No	No
DATA RETENTION	No	Yes	—	No	Yes	Yes	Yes
ADDRESS INCREMENTING BY ADDRESS REG. COUNTER	Yes	Yes	—	Yes	Yes	Yes	Yes
DRIVE CONFIGURATIONS							
Diode-transformer							
Diode-balun							
2 diode/line direct	X	X		X	X	X	X
4 diode/line direct			X				
SEPARATE REGISTER CLEAR	No	Yes	Yes	No	Yes	Yes	Yes
PARITY GEN. AND CHECK LOGIC	No	No	No	No	Yes	Yes	Yes
DATA TRANSFER MODE	SR**	SR**	SR**	SR**	DR**	SR**	SR**
LOGIC CIRCUITRY	Discrete	Discrete	Discrete	Discrete	Discrete	IC	IC
ENVIRONMENTAL FACTORS							
Operating temp. (°C)	0 to 65	0 to 50	0 to 50	0 to 65	0 to 50	0 to 50	0 to 40
Shock and vibration	Comm.	Comm.	Comm.	Comm.	Comm.	Mil.	Mil.
Temp. compensating currents	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wide temp. cores	Yes	No	No	Yes	No	No	No
MAINTAINANCE AIDS							
Internal or external exerciser	None	None	None	None	Internal	Internal	Internal
Indicator lights on flip-flops	No	Optional	No	—	Yes	Yes	Yes
Flip-flop set/clear controls	No	No	Yes	—	Yes	Yes	Yes
Shmoo plotting	No	No	No	No	Yes	Yes	Yes
Sense threshold adjustment	No	No	No	—	No	No	No
Inhibit current adjustment	No	Yes	Yes	—	No	No	No
Drive current adjustment	No	Yes	Yes	—	Yes	Yes	Yes

* Refers to "Basic Operating Module" (see preceding text)

** SR = single rail; DR = double rail

CORE MEMORY SYSTEMS (CONT'D)

MANUFACTURER	LOCKHEED				RCA, ELECT. COMP. & DEVICES	
MODEL	CI-200	CC-100	CE-100	CD-65	—	—
TIMING						
Cycle time (usec.)	2	1	1	0.65	1.0	1
Read access time (usec.)	0.8	0.4	0.45	0.375	0.375	0.4
BASIC STRUCTURE	3D-4 wire	3D-4 wire	3D-4 wire	2 1/2D-3 wire	3D-4 wire	3D-3 wire
BOM* CAPACITY						
Minimum words	4096	4096	4096	8192	8192	4096
Maximum word	4096	32,768	4096	32,768	16,384	4096
Minimum bits/word	4	4	4	8	2	4
Maximum bits/word	36	84	36	32	18	36
Bits/word increment	4	4	4	—	—	4
MODES OF OPERATION						
Full cycle	Yes	Yes	Yes	Yes	Yes	Yes
Split cycle	No	Yes	Yes	Yes	Yes	Yes
Half cycle	No	Yes	No	No	No	No
DATA RETENTION	Yes	Yes	Optional	Yes	Yes	Yes
ADDRESS INCREMENTING BY ADDRESS REG. COUNTER	No	Yes	Yes	Yes	No	Yes
DRIVE CONFIGURATIONS						
Diode-transformer					X	X
Diode-balun		X	X	X		
2 diode/line direct	X			X		
4 diode/line direct						
SEPARATE REGISTER CLEAR	No	Yes	No	Yes	No	No
PARITY GEN. AND CHECK LOGIC	No	Yes	No	Yes	No	Yes
DATA TRANSFER MODE	SR**	SR**	SR**	SR**	SR & DR**	SR & DR**
LOGIC CIRCUITRY	IC	Discrete	IC	Discrete	IC	IC
ENVIRONMENTAL FACTORS						
Operating temp. (°C)	-55 to 85	0 to 50	0 to 50	0 to 50	10 to 40	0 to 50
Shock and vibration	Mil.	Comm.	Comm.	Comm.	Comm.	Comm.
Temp. compensating currents	Yes	Yes	No	Yes	No	Yes
Wide temp. cores	Yes	No	Yes	—	No	No
MAINTAINANCE AIDS						
Internal or external exerciser	None	Either	Internal	Either	—	External
Indicator lights on flip-flops	No	Optional	Optional	Optional	Yes	No
Flip-flop set/clear controls	No	Optional	No	Optional	Yes	No
Shmoo plotting	No	Yes	Yes	Yes	—	Yes
Sense threshold adjustment	No	Yes	No	Yes	No	Yes
Inhibit current adjustment	No	Yes	No	No	No	Yes
Drive current adjustment	Yes	Yes	No	Yes	Yes	Yes

* Refers to "Basic Operating Module"

** SR = single rail; DR = double rail

CORE MEMORY SYSTEMS (Cont'd.)

MANUFACTURER	RCA, ELECT. COMP. & DEVICES		RAYTHEON COMPUTER	
MODEL	—	—	Nanolock	300
TIMING				
Cycle time (usec.)	5	0.5	0.3	0.9
Read access time (usec.)	1.5	0.25	0.25	0.3
BASIC STRUCTURE	3D-4 wire	2 1/2D-3 wire	2D-2 wire	2 1/2D-3 wire
BOM* CAPACITY				
Minimum words	8192	8192	256	8192
Maximum words	1024	16,384	4096	32,768
Minimum bits/word	4	2	4	4
Maximum bits/word	36	36	128	72
Bits/word increment	2	2	4	1
MODES OF OPERATION				
Full cycle	Yes	Yes	Yes	Yes
Split cycle	Yes	Yes	N/A	Yes
Half cycle	Yes	No	N/A	—
DATA RETENTION	Yes	Yes	Yes	Yes
ADDRESS INCREMENTING BY ADDRESS REG. COUNTER	Yes	Yes	No	No
DRIVE CONFIGURATIONS				
Diode-transformer	X	X	—	—
Diode-balum				
2 diode/line direct			X	X
4 diode/line direct	X	X		
SEPARATE REGISTER CLEAR	Yes	Yes	—	Yes
PARITY GEN. AND CHECK LOGIC	Yes	Yes	No	No
DATA TRANSFER MODE	SR & DR**	SR & DR**	SR**	SR**
LOGIC CIRCUITRY	IC	IC	Hybrid	Hybrid
ENVIRONMENTAL FACTORS				
Operating temp. (°C)	0 to 50	0 to 40	0 to 50	10 to 40
Shock and vibration	Comm.	Comm.	Comm.	Comm.
Temp. Compensating currents	Yes	Yes	No	Yes
Wide temp. cores	No	No	Yes	No
MAINTAINANCE AIDS				
Internal or external exerciser	External	Optional	No	Internal
Indicator lights on flip-flops	Yes	Optional	No	Yes
Flip-flop set/clear controls	Yes	Optional	No	No
Shmoo plotting	Yes	Optional	No	No
Sense threshold adjustment	Yes	Yes	Yes	No
Inhibit current adjustment	No	No	Yes	N/A
Drive current adjustment	Yes	Yes	Yes	Yes

* Refers to "Basic Operating Module (see preceding text)

** SR = Single rail; DR = Double rail

LOGIC CIRCUITS AND MODULES

Choosing logic circuits is a more complicated process today because there are more alternatives now than there have ever been. Only a few years ago the only major choice to be made was "make or buy". The advent of integrated circuits has introduced another major choice and has also made it appropriate to re-evaluate some areas (such as packaging and wiring methods) in which the decisions in recent years have been obviated by a "standard" way of doing things. The logic circuit decision-making process under today's technology proceeds in somewhat the following sequence.

- A. Integrated or discrete?
- B. If answer to "A" is "integrated":
 - 1. Make or buy decision is most likely "buy"
 - 2. What kind of IC and from whom?
 - 3. Packaging—Plug-in cards? Large circuit boards? 3-dimensional stacking? Mother-daughter boards?
 - 4. Interconnection: Wiring? Multi-layer Circuitry?
- C. If answer to "A" is discrete:
 - 1. Make or buy?
 - 2. Silicon or germanium?
 - 3. Packaging and interconnection?

Integrated Logic Circuits

During the past five years, the application of considerable expert engineering effort has moved integrated circuitry from an expensive, military-oriented technology to an industry-wide formidable breakthrough which is resulting in decreased cost, increased performance, and increased reliability. This breakthrough is at least as significant as was that caused by the advent of transistors ten years ago and the concomitant problems of re-education, device-selection, retrofit, etc. are at least as traumatic. IC techniques and device availability have been changing on practically a monthly basis, creating instant obsolescence for systems still on the drawing boards.

A survey of available IC devices will, therefore, inevitably be, to some extent, out-of-date by the time it reaches print, and the user is urged to supplement the information herein with the latest versions of manufacturers' literature and to keep current through the latest articles in COMPUTER DESIGN.

The three major areas of interest in IC's for the digital designer are:

- Standard logic circuits flip-flops, gates, etc.;
- Non-digital IC's and hybrid circuits;
- Large-scale integration (LSI): registers, counters, etc.

This survey is limited to the standard integrated logic circuits that are commercially-available from

the major semiconductor manufacturers.

The design considerations in choosing IC logic are basically the same as those which the digital designer has always evaluated in choosing a logic circuit: maximum operating frequency and propagation delay, fan-out, noise immunity, power requirement and dissipation, environmental characteristics, cost, adequacy of design, and the integrity and competence of the manufacturer. The functional characteristics of a line of IC's are imparted principally by the type of logic used. A review of the principal logic forms and their basic characteristics is presented below.

- RTL—Resistor-Transistor Logic. A direct translation of discrete-circuit design into integrated form: a pioneer IC. Highly reliable and easy to use. Limited fan-out. Noise immunity, logic swing, and propagation delay highly temperature-and load-sensitive.
- DCTL — Direct-Coupled Transistor Logic. RTL without a resistor in the base lead. Fan-in sensitive.
- DTL—Diode-Transistor Logic. Simple version is also a translation from discrete logic. DTL has better input impedance, noise immunity, and larger logic swings than RTL, but requires two power supplies. A modified version, called 930 DTL, uses one power supply, has lower power dissipation, better fan-out, lower propagation delay, better noise immunity, and good temperature stability. Radiation-resistant version also available.
- VTL — Variable-Threshold Logic. Modification of DTL, intended for use in high-noise environment. Good noise immunity and ground noise rejection. Requires two power supplies. Poor power/speed ratio. Limited fan-out.
- ECL—Emitter-Coupled Logic (also known as CML-Current-Mode Logic). Design tailored to IC's; not adapted from discrete-circuit design. Uses current-steering and non-saturating transistors. Very low propagation delay, high fan-in and fan-out, excellent noise immunity, excellent temperature stability, and it is insensitive to power supply variations. Susceptible to external noise and ground-line variations. Both the function and its complement available at the output. Some oscillation problems.
- CTL—Complementary-Transistor Logic. Similar to ECL in concept and performance. Not quite as fast, but more stable.

EQUIPMENT CHARACTERISTICS REVIEW

- **TTL** – Transistor-Transistor Logic. Modification of DTL whereby gating diodes are replaced with transistors. Output actively driven at both polarities. Low propagation delay, good fan-out, noise margin comparable to DTL. Tends to generate internal transient noise. Good production yield due to large allowable component tolerances.

An important consideration in the use of IC's is the suitability of the IC packaging to the intended use. The three packages in common use are listed below:

- TO-5 can – transistor-type cylinder, typically 0.36" diameter by 0.175" high, with ten leads in 1/4" diameter circle extending from the bottom.
- Flat-packed – typically 1/8" x 1/4" x 0.05", with 14 leads on 0.05" spacing, seven on each of the 1/4" edges extending outward in the major plane of the flat-pack.
- Dual-in-line – typically 1/4" x 3/4" x 0.2" "coffin", with 14 leads on 0.1 spacing, seven on each of the 3/4"sides extending downward perpendicular to the major plane of the package.

Large-Scale Integration

We have defined LSI as monolithic devices which comprise sub-units such as registers, counters, adders, etc. MOS (metal oxide-silicon) devices are the principal manifestation of these devices today. They offer the advantages of low cost per function and low power consumption. Present disadvantages include limited speed capability and poor noise margins. With the exception of shift registers, MOS technology is primarily implemented through a custom-design process.

Logic Modules/Cards

In the distant past, in the dark ages of electronic equipment, there were no circuit modules. The active circuit elements (known as vacuum tubes) plugged into sockets, and all other components were soldered in neat rows between lines of insulated studs. Typical corrective maintenance procedure was to check waveforms to isolate the problem to one circuit stage, and, if replacing the tube did not correct the problems, the soldered-in components were checked with ohmmeter and megger, after unsoldering one end.

The idea of modularity, whereby the entire circuit stage could be replaced, the equipment returned to service, and repair done "off-line", was initially implemented in a variety of forms such as turrets, which plugged into the octal sockets, and the printed-circuit board with the card-edge connector. The advent of transistors eliminated the awkwardness of mounting a vacuum tube on the printed circuit board and today there is no construction technique in general use in the computer industry other than printed circuit modules.

If there is nearly universal agreement on the desirability of modular construction using printed circuit boards, there is nonetheless, very little agreement beyond that point. Each company or en-

gineering group has resolved the design tradeoffs in terms of its own needs and judgment, and this has, expectedly, produced a wide variety of implementation. Some of the points on which each module user is free to—and should—make his own decisions are discussed below.

- Few versus many types—all logic design can be accomplished with the use of only three kinds of circuits: an AND gate, an inverter, and a flip-flop. However, available logic module product lines offer from 11 to 55 different logic modules, with the average being about 20. Some of tradeoff factors in choosing a few versus many types are:
 1. Fewer module types should result in greater mass production efficiency, therefore in lower module prices;
 2. More module types give logic designer greater flexibility, therefore a given logic design may be accomplished using less modules, thus reducing power and space requirements;
 3. Fewer module types result in lower spare parts complement and lower documentation requirement, thus reducing costs;
 4. Fewer module types reduce the learning problem for designer, debugger, and maintenance man.

General-purpose versus functional—should only general-purpose logic boards (gates and flip-flops) be used? Or should half-adder, counter, and register boards be used? Or should the logic be designed for a system and then laid out on unique boards? In most cases the decision has been to use a mix of the first two alternatives.

- Interconnection method—should wires with wire-wrap, solder, paper pin, or Termipoint be used? Or should the component boards plug into a printed-wire "mother-board"? Should multi-layer boards be used to increase the logic density on the board and decrease the effect of the expensive edge-card connections?
- Module content—with the great increases in reliability brought on by integrated circuits, should the module be made to contain more functions? Should replaceability be upgraded to the sub-unit level?

Standard Families of Modules

The tradeoffs in implementing a digital system with purchased logic modules will be affected by the characteristics of available module families. Once a "buy" decision is made, of course, comparison of the available modules must be made as the basis for the choice of a particular module family. The characteristics which should be investigated are as listed.

EQUIPMENT CHARACTERISTICS REVIEW

- Maximum operating frequency and propagation delay—do the modules operate fast enough for the requirement? Do they operate overly-fast for the requirement, introducing fast edges and unnecessary critical timing? Is there a mix of compatible modules operating at different speeds, which might best solve the requirement?
- Fan-out—is the fan-out (driving power) sufficient so that logic functions can be implemented efficiently? Low fan-out introduces the need for intermediate power amplifiers which must be considered as a part of the total cost of doing the job with a given module family.
- Noise rejection—is noise immunity sufficient for the amount of logic, type of interconnection, and environment of the system?
- Power requirement—cost of power must be added in as a part of the total cost of doing the job with a given logic module family.
- Type of interconnection available—does it fit with the best approach for the given system?
- Module types available—are the types of logic, functional, and other modules available in a family sufficient to offer the optimum mix. Are there interfacing modules, pulse shapers, oscillators, A-D converters, etc.?
- Available accessories—are card cages, power supplies, grounding system, card identification decals, logic symbol templates, custom-designed modules, etc., available from a given manufacturer of logic modules?
- Environmental characteristics—do the modules meet temperature, humidity, vibration, fungus, and size and weight requirements of a given system?
- Adequacy of design—are test points provided? Is there unique card-position keying? Are the loading rules simple? Are the circuits short-circuit-proof? Can components be replaced easily? Are logic wiring and wiring changes easy to perform?
- Support—is there an adequate applications manual? Is field support available? Are spares readily available? Can the modules be repaired “off-line”?
- The manufacturer—what is his reputation and experience? Is there sufficient field experience with his modules?

Product Summary Charts

On the following pages appear charts summarizing the specifications of available integrated logic circuits and logic modules. It is not practical to list in a summary chart all of the characteristics discussed above, although all should be considered when choosing a given product line.

INTEGRATED CIRCUIT LOGIC CARDS

MANUFACTURER	SERIES	MAX. OPERATING FREQUENCY (Megahertz)	IC LOGIC TYPE	FANOUT	TEMP. RANGE (°C)	NO. OF LOGIC CARD TYPE	NO. OF FUNCTION CARD TYPE	NO. OF MISC. CARD TYPE	COST PER J-K FLIP-FLOP* (\$)
ABACUS DIV. ICC	I	5	Urilogic	10-12	-20 to 85	9	6	11	17.50
	I-100	5	DTL		0 to 70	4	6	6	
	Interlogic	5	DTL	2-8	0 to 70	8	4	8	17.22
APPLIED DEVEL.	ADC-13	5	SPE and MOS	4-9	-55 to 125	11	5	9	16.25
CAL. SYSTEMS COM.		5	DTL		-55 to 125	9	22	35	
CAMBRIDGE THER.	780	5	DTL	5-10	0 to 70	34	110	7	10.83
COMPUTER LOGIC	30/40	5	Mod. DTL	20-25	0 to 70	10	7	10	13.20
CONTROL LOGIC	C	5	TTL	6-24	0 to 70	6	12	11	13.50
	C-120	20	TTL	3-5	0 to 75	3	12	1	23.10
DATA TECHNOLOGY	Blue 400	5	DTL	8 (typical)	0 to 50	12	3	12	9.75
	Blue 500	5	DTL	5 (typical)	0 to 70	13	9	12	9.75
	Black	5	DTL	12 (typical)	0 to 70	15	9	20	10.00
DECISION CONTROL	Micro Versalogic	5	DTL	6-10	0 to 70	8	9	8	10.83
DIGITAL PRODUCTS		5	Urilogic	4-12	0 to 70	12	3	6	11.70
ENGINEERED ELECT	EEecologics	20	DTL	4-11	0 to 75	3	12	1	23.10
HONEYWELL, 3C DIV.	u-PAC	5	DTL	7-8	0 to 55	9	10	10	14.19
MONITOR SYSTEMS	5 Monilogic	5	DTL	4-10	0 to 70	7	19	16	13.80
RAYTHEON COMPUTER	M	2	DTL		0 to 70	9	8	13	
SDS	T	10	DTL	14	+5 to 71	10	8	17	15.33
SEL	8500	5	RTL	5 (typical)	+15 to 55	6	29	77	13.50
VITRO ELECT.	3000	5	DTL	5-15	0 to 70	4	23	14	22.50
WYLE LABS.	M	5	DTL	3-25	0 to 70	8	3	6	15.20

* Cost—figure-of-merit based on 25-card quantity price.

INTEGRATED LOGIC CIRCUITS

CIRCUITS ARE LISTED IN ASCENDING ORDER BY GATE SPEED

MANUFACTURER	SERIES	LOGIC TYPE	PROPAGATION DELAY (NANOSECOND)		FF MAX. FREQ. (MHz)	FANOUT	POWER (mW)		NO. OF CIRCUIT TYPES	NOISE REJECTION (Mv)	TYPE OF PACKAGING
			GATE	FLIP-FLOP			GATE	FLIP-FLOP			
GENERAL INSTRUMENT	MEM	MOS	350	725	0.5	5	—	—	3	—	—
MOTOROLA SEMICON.	MHTL	DTL	100	—	—	—	—	—	—	—	—
TEXAS INSTRUMENT	S1/S1R	RCTL	65	300	—	4-5	2	12	11	350	Flat
MOTOROLA SEMICON.	MC650	VTL	50	60 typ	—	4-5	20-150	—	—	2000-5000	Flat, Can
NATIONAL SEMICON.	2NC	RTL	45	45	10	2-7	4	12	7	250	Flat, Can
SPRAGUE ELECTRIC	US-0900	RTL	40	NA	—	—	4	NA	7	150	Flat, Can
FAIRCHILD SEMICON.	MWuL	RTL	40	120	—	1-5	2	12	7	275 min.	Can
RAYTHEON SEMICON.	RM	DTL	40	48	—	11	11	11	19	550	Flat, Can
TEXAS INSTRUMENT	1700	RTL	35	70	—	3-4	4	15	7	150	Flat, Can
MOTOROLA SEMICON.	MC200	DTL	30	60	10	5-8	15	16	14	500	Flat, Can
MOTOROLA SEMICON.	MC930/MC830	DTL	30	30	12	3-12	8	—	11	—	Flat, Can, or Dual In-Line
PHILCO MICRO.		RTL	30	70	—	4-5	4	20	8	60	Flat, Can
PHILCO MICRO.		DTL	30	25	—	4-8	20	16	21	1000 min.	Flat, Can
SIGNETICS	SU, LU	Utilogic	30	65	—	5-17	18	90	9	600 min.	Flat, Can
SIGNETICS	600A	DTL	30	65	—	2-8	20	120	7	800 min.	Dual In-Line
SPRAGUE ELECTRIC	SU300K	Utilogic	30	—	4	5-17	18	90	9	1200	Can
TEXAS INSTRUMENT	53,73	MDTL	30	60	—	10	10	27	14	300	Flat, Plug-In
MOTOROLA SEMICON.	MC908G	RTL	27	50	—	2-4	2	15	10	—	Can
MOTOROLA SEMICON.	MC700G/MC700P/MC800P	MRTL	27	35	—	2-10	12	78	25	—	Dual In-Line, Can
SPRAGUE ELECTRIC	SE100J	DTL	25	—	12	6-8	15	40	18	1000	Flat
FAIRCHILD SEMICON.	DTuL	MDTL	25	50	—	3-15	5	30	8	750	Flat, Can, Dual In-Line
ITT SEMICON.	MIC	MDTL	25	50	—	3-15	5	30	8	750	Flat, Can, Dual In-Line
SIGNETICS	SE, CS	DTL	25	23	—	4-20	23	150	23	1000	Flat, Can
TEXAS INSTRUMENT	15930	DTL	25	50	20	7-8	5	20	10	750	Flat, Plug-In
SPRAGUE ELECTRIC	SE400J	MDTL, TTL	23	—	9	7	4	9	6	1000	Flat
STEWART-WARNER	SW900	DTL	20	—	10	7-10	8	35	8	700 min.	Flat, Can
TEXAS INSTRUMENT	54,75	TTL	13	40	25	10	10	60	9	1000	Flat, Plug-In
TEXAS INSTRUMENT	54930,74930	TTL	13	40	—	10	10	60	7	1000	Flat, Plug-In
FAIRCHILD SEMICON.	uL	RTL	12	—	—	—	19	56	9	400 typ	Can
STEWART-WARNER	SWG, SWF	TTL	12	—	20	6-26	15	50	32	1000 min.	Flat, Can
NATIONAL SEMICON.	2NB	RTL	12	14	10	2-16	27	40	15	250 min.	Flat, Can
SPERRY SEMICON.	RTL-900	RTL	12	40	20	2-5	17	80	11	—	Flat, Can
MOTOROLA SEMICON.	MC500/MC400	TTL	10	40	20	1-15	15	—	15	900	Flat or Dual In-Line
FAIRCHILD SEMICON.	FuL	RTL	10	25	—	16 typ	3	40	9	100 min.	Can
SYLVANIA SEMICON.	SUHLI	TTL	10	—	20	6-7	15	50	19	1000 min.	Can
SPRAGUE ELECTRIC	SE800J	TTL	10	—	30	5-10	20	70	9	1000	Flat
MOTOROLA SEMICON.	MC-350	ECL	8	7.5	15	15-25	54	87	19	200 min.	Flat, Can
PHILCO MICRO.	Super RTL	RTL	8	—	30	2-4	4	—	10	—	Flat
RADIATION, INC.	200	DTL	7	20	35	8-12	10	95	10	800 min.	Flat
RADIATION, INC.	300	DTL	7	20	35	5	10	95	8	800 min.	Flat
RADIATION, INC.	500	DTL	7	7	—	5-7	10	20	10	800 min.	Flat
TRANSITRON	HLTTL	TTL	6	20	40	7-15	22	—	39	1000	Flat, Dual In-Line
WESTINGHOUSE	WM200	DTL	6	—	15	9-11	23	45	41	550 min.	Flat, Can
SYLVANIA SEMICON.	SUHL II	Sat. TTL	6	—	30	5-6	22	55	9	1000	Flat, Dual In-Line
STEWART-WARNER	SW300	ECL	6	10	30	—	49	52	8	—	Flat, Can
TEXAS INSTRUMENT	70	ECL	5	NA	—	—	40	NA	2	250	Flat, Plug-In
MOTOROLA SEMICON.	MC-1000	ECL	5	—	70	15-25	40	—	11	—	Dual In-Line
MOTOROLA SEMICON.	MC-1050	CML	3.5	NA	NA	10	110	NA	—	—	Flat

DISCRETE-COMPONENT LOGIC MODULE/CARDS

Manufacturer	Series	Max. Operating Frequency (Megahertz)	Si or Ge	Fanout	VDC Logic Levels	Temp. Range (°C)	No. of Logic Types	No. of Functional Types	No. of Misc. Types	Cost* Per J-K Flip Flop
CAMBRIDGE THER.	—	0.1	Ge	2-8	-6,0	-35 to 65	26	2	15	14.35
COMPUTER LOGIC	E	0.1	Ge	10	-10,0	—	—	—	—	—
	L	0.3	Ge	10	-10,0	—	—	—	—	—
	S	1	Si	7	—	—	—	—	—	—
	M	2	Ge	7	-10,0	—	—	—	—	—
	H	5	Ge	7	-10,0	—	—	—	—	—
CONTROL EQUIPMENT	600	0.1	Ge	6-7	-6,0	-45 to 65	12	2	17	8.37
	700	0.5	Ge	6-7	-6,0	-45 to 65	12	2	17	10.06
	800	2	Ge	5-6	-6,0	-45 to 65	12	2	17	14.64
	900	10	Ge	4-5	-6,0	-45 to 65	10	1	17	14.64
DECISION CONTROL	10	0.2	Ge	1-2	-10,0	-10 to 55	11	0	29	17.00
	20	2	Ge	3-12	-10,0	-10 to 55	10	0	29	30.00
	30	8	Ge	3-12	-10,0	-10 to 55	9	0	22	40.00
ELECTRONIC MODULES	—	0.1	Ge	1-5	-6,0	-55 to 70	7	7	4	4.75
	—	0.25	Ge	2-6	-6,0	-55 to 71	12	12	13	12.17
	—	2	Ge	2-5	-6,0	-55 to 71	11	13	13	20.90
	—	2	Si	1-5	+6,5,0	-55 to 125	7	11	13	23.63
ENGINEERED ELECTRONICS	Q410	0.025	Ge	4	-6,0	-20 to 55	8	0	3	6.42
	Q420	0.1	Ge	4	-6,0	-20 to 55	4	0	3	6.42
	GA300	0.1	Ge	—	-6,0	-55 to 71	8	2	21	11.50
	Q430	1	Ge	4	-6,0	-20 to 55	3	0	3	8.52
	Q480	1	Si	4	+6,0	-55 to 125	1	0	3	NA
	GA200	1	Ge	10	-6,0	-55 to 71	7	1	24	10.67
	GA100	10	Ge	5	-6,0	-55 to 71	6	1	30	23.75
GEN. APPLIED SCIENCE LABS.	—	1	Ge	4-10	-8,0	0 to 55	7	5	25	31.50
HONEYWELL COMPUTER CONTROL DIV.	S-PAC	0.2	Ge	6-7	-6,0	-20 to 55	10	7	28	13.81
	S-PAC	1	Ge	6-7	-6,0	-20 to 55	10	7	31	19.19
	S-PAC	5	Ge	4-5	-6,0	-20 to 55	10	9	31	19.19
INTERCONTINENTAL INSTRUMENTS	—	3	Ge	7-8	-3,0	0 to 55	7	2	9	NA
	—	3	Si	3-8	+3,0	-55 to 100	7	2	9	NA
	—	10	Ge	5-6	-3,0	0 to 55	7	2	9	NA
	—	10	Si	3-7	+3,0	-55 to 100	7	2	9	NA
IBM CORP.	—	—	—	—	-6,0	—	12	5	14	17.25
MAGNETIC SYSTEMS	MS-1000	1	—	1-4	—	-15 to 85	15	0	7	—
NAVIGATION COMPUTER	MC	1	Ge	6	-6,2,0	0 to 55	—	—	—	—
RAYTHEON COMPUTER	—	0.2	Ge	—	-10,0	0 to 55	8	8	29	12.13
	—	1	Ge	—	-10,0	0 to 55	8	8	26	16.76
	—	5	Ge	—	-10,0	0 to 55	8	8	20	21.83
	—	20	Ge	—	-10,0	0 to 55	3	0	12	63.05
SCIENTIFIC DATA SYSTEMS	C	0.3	Si	—	+8,0	0 to 100	23	2	27	—
	H	1	Si	—	+8,0	0 to 100	20	2	27	—
	L	8	Si	—	+8,0	0 to 100	7	—	27	—
SPACE CRAFT	2Z	1	Ge	2-6	-6,0	0 to 50	5	3	10	15.44
SQUARE D	NORPAK	0.025	Ge	4	-20,0	—	5	3	9	NA
SYSTEMS ENGINEERING LABS.	8000I	0.150	Ge	1-4	-6,0	0 to 50	3	2	5	—
	8000II	1	Ge	1-4	-6,0	0 to 50	3	2	5	—
WYLE LABS.	L	0.050	Ge	—	-10,0	0 to 50	7	4	9	NA
	M	0.2	Ge	—	-10,0	0 to 50	9	5	23	10.00
	H	1	Ge	—	-10,0	0 to 50	9	5	23	12.50

*Cost-figure-of-merit based on 25-card quantity price.

SURVEY OF COMMERCIAL TIME-SHARING FACILITIES

The most rapidly-emerging development in the computer industry is the concept of time-sharing. There is sufficient evidence that time-shared computer systems are moving out of the laboratory and now have a potential for business use. Time-sharing systems offer large computing and storage capabilities, provide rapid response to direct interrogation, and can be accessed from remote locations. The time-sharing concept developed from the need to provide the computer user with an efficient, quick and, hopefully, economical service.

In a time-shared system, multiple users, through remote terminals such as teletypewriters or display tubes, have access to a central computer. Each user communicates with the computer in what is called a conversational mode. This is a dialogue which the user initiates when the terminal is dialed into the computer and continues while he composes and executes his program or poses his questions. During the process of composing the program, each statement is syntactically checked, and, if an error is found, the user immediately receives an error diagnostic. An error of this nature, one of syntax, is therefore corrected before execution is attempted. During the execution phase, the user is able to monitor what is taking place, and if his program is so written, may re-direct the computation process. It is only when the user is satisfied with his results that the conversational mode or dialogue ends. While each user proceeds as though he is the only one using the system, there are in fact many users executing their own programs. A time-shared system is one in which multiple users, often remote, have access to a central computer at the same time, each requesting the computer to execute his application, and each receiving results in the same quantum of time.

Advantages of Time-Sharing

Time-shared systems were developed to maximize throughput and minimize turn-around time which in many conventional batch-processing systems, especially at peak loads, is relatively inefficient. In the batch-processing system there are the problems of scheduling runs and set-up time. Some of the newer third generation computers now have complex operating systems that perform many of the scheduling activities to optimize system capabilities. These operating systems are a step toward time-sharing. In a time-shared system, scheduling is accomplished on a dynamic basis by the system's Executive or Monitor. Therefore, the system is constantly adjusting to multiple user demands for service. Time-sharing provides for more effective utilization of the computer facility and recognizes user requirements on a dynamic basis.

In the past, computers have had a specialized role in terms of applications. The basic functional areas have been business computation, scientific computation, and monitoring and controlling real-time processes, with each function having a special-

ly-adapted computer. Now, these three separate areas may be combined and executed simultaneously on a time-shared computer facility. In terms of economic considerations, a time-shared system may be justified by the immediacy, flexibility, and convenience offered to the multiple users of the system. The engineer working on a project in research and development and the business executive desiring operational information can both use the same computer on a time-shared basis. They have remote access to a central data bank for timely retrieval of information and a tremendous capacity for computational activity.

The engineer who must perform a series of calculations and analyze the results to determine the best design for a particular product would perform the following steps in a typical batch-processing system. First, he would need a knowledge of a scientific programming language so that he could develop a computer program. After writing the coded instructions it would then be converted to punch cards or paper tape for input to the computer. At the time his program is scheduled to be run, the computer operator would load the program into the computer for execution. If an error had occurred during the coding or conversion to input media, the program would not run, and the program would be sent back to the engineer for correction. Following this process, the program would then be re-scheduled for a computer run. At this time, the program might run to conclusion and the results would be forwarded to the engineer. If the results did not meet the specifications, the constraints would have to be changed and the process repeated. This approach is time-consuming and extends the length of the job on which he is working.

In a time-shared system, the process would proceed quite differently. The engineer would sit down at a terminal located near his area of work, even though remote from the computer facility. He would establish connection with the computer and then instruct the computer in the operations it is to perform. If an error is detected in the process, the computer would send back an error message so that immediate correction could be made. After supplying the necessary data, the program would be executed. During this time, the engineer would be able to control the operation and, if the desired results were not achieved, he could stop the processing and enter new constraints. Finished results would be calculated and the engineer could then save the program for future reference. All of this is achieved in one sitting at the terminal. The payback is in terms of productivity and man hours of work saved by using time-sharing.

Equipment Characteristics

Hardware used in the time-sharing system is basically the same as that found in many conventional systems. The differences would be in the controllers for the various units in order to interface them with the central computer facility. The greatest hard-

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ware demand is the apparent endless need for memory. To satisfy the memory requirements, a hierarchy of storage such as drums, discs, etc. is used. While the price for high-speed core memory is decreasing, it is not yet economical to use only this form of memory. In order to increase the storage capacity of the system, therefore, other units are added which are less expensive but have larger storage capacity but slower access times. Main core memory normally has an access time of 5 microseconds or less and many now have nanosecond speeds, whereas mass storage devices operate in the 25-400 millisecond range. This difference in speed may be tolerated in a time-shared system because of software scheduling techniques and the time-shared computer's ability to overlap functions. The overhead in a time-shared system consists of the system executive, programming language compilers and assemblers, job schedulers, queuing systems, facilities for debugging and editing, and accounting routines. In addition, there is a unique requirement for memory allocation, providing each user the illusion of exclusive use of the memory. The time-shared system keeps track of memory allocations and manipulation of memory files.

Software Considerations

Software is a vital part of the time-shared system, and is normally a very expensive part of the system. In the past, software in a batch-processing system has been generally oriented toward the solution of a given application; it did not always utilize the computer system in the most efficient manner. However, with the operating systems available with new third generation computers, software is becoming more efficient and flexible.

Time-shared software is designed to make the best use of the system's facilities. This is achieved by scheduling operations so that the central processor unit (CPU) is used as much as possible and as steadily as possible. Delays brought about by data transmission from discs, drums, magnetic cards, etc. must not hold up execution of operations in the CPU. By scheduling another activity that will require the use of the CPU, the software compensates for the time it takes to get the required information from some recording media into main memory. Other unique functions performed by the software include: handling requests from terminals; allocating facilities within the system; controlling all input/output operations; and tabulating accounting information for billing of time logged on the system.

The use of re-entrant compilers and assemblers is becoming more prevalent in time-shared systems. The advantage of such a compiler or assembler is the elimination of the need to swap the software package out of memory as successive users require the compiler or assembler. The amount of mass storage allocated for system's operations is thereby reduced. With this reduction in system overhead the user is allowed more storage for his programs and data. Re-entrant compilers essentially store only the status of the user's job and the program source language at the time of swapping the user out of core storage. This technique requires only one copy of the compiler rather than several copies, each of which may be in a different stage of compilation.

Economics

User costs involve the following items in a time-shared system: the remote terminal; the cost of communications between the terminal and the computer; and computer usage time. The terminal may consist simply of a teletypewriter which ranges in cost from \$65 per month and up, or a visual display device such as a cathode ray tube which may run from \$300 to \$600 per month.

Communication costs can be significant in a time-shared system. Currently, wire communication costs range from \$1 per-mile-per-month for a teletypewriter grade channel to \$45 per-mile-per-month for a Telpak D channel. Most common is a voice grade line at \$2 to \$3 per-mile-per-month. WATS (Wide Area Transmission Service) services can also be utilized at "no charge" for the individual call. The cost for WATS is a fixed-charge per month ranging from \$240 to \$2,000 per month for nationwide coverage.

Commercial usage of the computer itself is usually calculated on the basis of time connected to the computer. Charges range from \$5 to \$15 per hour for connection time. Charges for actual computer time used will vary greatly according to equipment being utilized. There are usually moderate charges for storage of programs and data.

The data processing installation of today is constantly being expanded or upgraded and substantial costs can be incurred. Expansion costs not only represent additional space and hardware but also the expenses for converting programs to new equipment, maintaining compatibility if more than one system is involved, assuring efficient data flow, updating documentation to reflect changes that may be required, and education of the personnel required to operate the new equipment. The question to be considered is whether or not the conventional batch processing facility satisfies the computing requirements as economically as using a time-shared system. Buying time on a time-shared computer usually offers the advantage of giving the individual user more computing power and more advanced facilities than he could normally afford or justify. The combination of several smaller systems does not normally equal one larger system, or put another way, the whole is greater than the sum of its parts.

Future Outlook

Despite the fact that time-sharing is becoming a reality, there are still many obstacles to overcome. Education of the user on how to apply and maximize use of broad-based data files will take time. Most applications are currently centered on engineering or research tasks with some applications designed to serve the financial community. Outside these areas new applications are only now being developed to serve the general business community.

The concept of a general multi-purpose computer utility seems to be some time away in spite of the publicity this subject has been receiving. Instead, specialized "utilities" will provide services tailored for functional areas such as personnel recruiting systems, financial analysis, marketing research, and industry information systems incorporating common data banks to industries such as steel, insurance, aircraft, etc. The banking and retail industries are expected to launch a joint venture

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to develop and market consumer credit and retail sales information systems. Large industrial firms will develop their own intra-divisional time-sharing systems to meet management requirements.

The vast potential of time-sharing will be significantly influenced by the success of current pioneering activities in developing economic applications for the business market. Universities such as MIT, Dartmouth, University of California, Carnegie Tech, etc. have made major inroads into software development and feasibility studies. Additionally, computer manufacturers have shown varying degrees of success with on-line users for scientific computation purposes. Even though experimental systems have proved successful, general acceptance of time-sharing is not yet fully realized although it appears to be inevitable.

Time-Sharing Facilities Survey

The map of the United States included in Table 1 indicates the geographical distribution of commercial time-sharing facilities. While services are limited in portions of the Mid-West and South at this time, it will not be long before these areas see expanded coverage. Computer Sciences Corporation is expanding its network in the Northwest and Com-Share is planning three more additions to its facilities this year. Allen-Babcock with its communication controllers located 400 to 3000 miles from their computer facility will provide more distant users with time-sharing services. As new facilities become operational, they will be reported in forthcoming issues and supplements of COMPUTER INDUSTRY ANNUAL.

Following this text is a summary chart of Commercial Time-Sharing Facilities which include only the systems which were operational on or before January 1, 1967. The chart includes general-purpose systems as well as two special-purpose systems; the latter being the Data Text system offered by IBM and a Text Editing and Typesetting system offered by VIP Systems. Computer Sciences Corporation offers a commercial service in Richland, Washington which is now being upgraded to a Univac 1108 from an 1107, and will be available during the third quarter of 1967. Information regarding this system and others will appear in the updating supplements of COMPUTER INDUSTRY ANNUAL.

The applications shown in the chart provide general indications of how the systems are being used by individual users. Today, the majority of time-sharing users are engaged in purely computational work rather than processing jobs.

Queuing systems, or the manner in which the next user to be served is determined, are almost as varied as there are time-sharing systems. The chart indicates some of the considerations taken into account in determining the sequence of users. For those systems which are indicated as being Round-Robin, it is not necessarily just the next user which must be determined but several subsequent users as well. Depending upon what command the user has entered from his remote terminal, there is a built-in priority involved. For example, certain commands take preference over others and will be executed first. The queuing algorithm is a very important part of a time-sharing system for it controls the primary use of the system. Thus, when the question of response time is considered it is

dependent not only on the queuing system but also on the job mix in the computer system.

If we consider a time-sharing system which ser-

TABLE 1 COMMERCIAL TIME-SHARING FACILITIES

(Planned or in operation)

COMPANY	LOCATION	COMPUTER	I/O PROCESSOR
GE Information Systems Division	Phoenix, Ariz.	GE 235	Datnet 30
	Berkeley Cal.	GE 235	Datnet 30
	Los Angeles, Cal.	GE 235	Datnet 30
IBM Corporation			
Data Text Service	Los Angeles, Cal.	IBM 1460	
Quiktran Service	Los Angeles, Cal.	IBM 7044	IBM 7740
Data Text Service	San Francisco, Cal.	IBM 1460	
Allen-Babcock	Palo Alto, Cal.	IBM 360/50	
Tymshare	Palo Alto, Cal.	SDS 940	
C. E. I. R.	Washington, D. C.	GE 235	Datnet 30
GE Information Systems Div.	Washington, D. C.	GE 235	Datnet 30
VIP Systems	Washington, D. C.	IBM 1441	IBM 1448
GE Information Systems Div.	Chicago, Ill.	GE 235	Datnet 30
IBM Corporation	Chicago, Ill.	IBM 1460	
	Quiktran Service	IBM 7044	IBM 7740



Bolt, Beranek & Newman	Cambridge, Mass.	PDP-7	PDP-8
Keydata Corporation	Cambridge, Mass.	UNIVAC 491	
Dial-Data	Newton, Mass.	SDS 940	
GE Information Systems Div.	Boston, Mass.	GE 235	Datnet 30
Com-Share	Detroit, Mich.	SDS 940	
GE Information Systems Div.	Detroit, Mich.	GE 235	Datnet 30
Renown Properties	Minneapolis, Minn.	GE 225	Datnet 30
Applied Logic	Princeton, N. J.	PDP-6	(2) PDP-8
IBM Corporation	New York, N. Y.	IBM 1460	
	New York, N. Y.	IBM 7044	IBM 7740
GE Information Systems Div.	Schenectady, N.Y.	GE 235	Datnet 30
GE Information Systems Div.	Cleveland, Ohio	GE 235	Datnet 30
IBM Corporation	Cleveland, Ohio	IBM 460	
	Cleveland, Ohio	IBM 7044	IBM 7740
	Philadelphia, Pa.	IBM 1460	
	Philadelphia, Pa.	IBM 7044	IBM 7740
GE (Missile & Space Div.)	Valley Forge, Pa.	GE 235	Datnet 30
Computer Sciences Corp.	Richland, Wash.	UNIVAC 1108	

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COMMERCIAL TIME-SHARING-FACILITIES

COMPANY	ALLEN-BABCOCK	APPLIED LOGIC	BOLT, BERANEK, AND NEWMAN	COM-SHARE
DATE SYSTEM OPERATIONAL	9/1/66	1/15/66	9/28/65	1/1/67
CENTRAL PROCESSOR	IBM 360/50	PDP-6	PDP-9	SDS-940
I/O PROCESSOR		(2) PDP-8	PDP-8	
CORE STORAGE				
Total in system	2,304K	32K	24K	64K
For each user	20K	20K	20K	16K
MASS STORAGE (total)	428 million bytes	6 million char.	5 million char.	182 million char.
REMOTE TERMINALS	IBM Selectric, Teletype models 28, 32, 33, 35	Teletype models 33, 35 CRT display	Teletype models 33, 35	Teletype models 33, 35
LANGUAGES				
Conversation mode	PL/I	DDT Debug Language	TELCOMP	CAL, QED, FORTRAN IV, ALGOL, DDT, Assembly
Background mode	PL/I, FORTRAN IV, COBOL, ALGOL, Assembly	FORTRAN IV, Macro 6	None	
RE-ENTRANT COMPILERS & ASSEMBLERS	Yes	No	No	Yes
QUEUING METHODS	Commutator-driven scheduling system	I/O Completion, elapsed time core size. Round-robin in these 3 levels	Round-robin	Binary logarithmic with heuristic modifications
MEMORY PROTECT TECHNIQUE	Protect keys, read-only option	Protection relocation registers	Interpretive execution	Paging, illegal instructions, memory trap
DATA FILE PROTECT TECHNIQUE		Access restricted by user. Info. stored in file directory	File name and user number checked by executive	Passwords, user name and number, file name
NO. OF SIMULTANEOUS USERS	90	15	32	30
USER PRIORITIES ASSIGNED	Special cases only	Yes	No	Yes
RESPONSE TIME (at 80-100% system usage)	2 sec.	2 to 3 sec.	0.5 sec.	3 sec.
CURRENT USER LOCATIONS (from CPU)				
Under 1 mile	26%	25%	8%	10%
1 to 20 miles	50%	35%	76%	20%
20 to 100 miles	0%	25%	8%	50%
Over 100 miles	24%	15%	8%	20%
GENERAL APPLICATIONS				
Inventory				X
Sales analysis	X	X	X	X
Order entry	X			
Scheduling		X	X	X
Personnel		X		
Financial	X	X	X	X
Accounting	X	X		X
Simulation studies	X	X	X	
Engineering calculations	X	X	X	X
Program debugging	X	X	X	X
Scientific	X	X	X	X
Educational	X		X	X
Text editing				
Typesetting				
COSTS				
Line connection time	None	\$5/hour		\$10 to 40/hour
CPU usage time		None	None	\$2.50/minute
Storage per month	Data cell :\$2/100K Disc file: \$10/100K	Tape: \$1/1K	depends on usage time	First 60K char free, \$4.25/10K additional char.

vices 30 users simultaneously and 29 of the users are asking for a listing of their programs, the one remaining user has all of the computing power of the machine to himself. In this situation, the single user will have very fast response time as opposed to the situation where all users are vying for computation time. What the actual priorities may be in any one system are, however, dependent on how the system has been defined and what the long-term objectives are.

Some systems have incorporated a smaller input/output processor which is separate from the central processor. The purpose in having the secondary processors is to free the central processor from having to receive characters directly from remote terminals, assemble them into messages, check for possible errors, and retransmit characters back to the remote terminals. The benefit of having the separate I/O processor then is to relieve the central processor from routine housekeeping activities

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COMMERCIAL TIME-SHARING FACILITIES (Cont'd.)

COMPANY	GENERAL ELECTRIC INFORMATION SYSTEMS DIV.	IBM CORP. DATA TEXT SERVICE	IBM CORP. QUICKTRAN SERVICE	TYMSHARE, INC	VIP SYSTEMS
DATE SYSTEM OPERATIONAL	10/30/65	9/8/66	8/30/65	11/1/66	1/15/67
CENTRAL PROCESSOR	GE-235	IBM-1460	IBM-7044	SDS-940	IBM-1441
I/O PROCESSOR	Datnet 30		IBM-7040		IBM-1448
CORE STORAGE					
Total in system	16K	16K	32K	65K	
For each user	6K	Variable	4K	16K	As required
MASS STORAGE (total)	20 million char.	86 million char.	56 million char.	72 million bytes	135 million char.
REMOTE TERMINALS	Teletype models 33, 35	IBM-2741	IBM-1050	Teletype models 33, 35	IBM-2741
LANGUAGES					
Conversation mode	Basic ALGOL, FORTRAN	ENGLISH	FORTRAN	CAL, FORTRAN II AND IV, TEXT EDITOR, ALGOL, Assembly	English
Background mode	GAP	None	None	CAL, FORTRAN II AND IV, TEXT EDITOR, ALGOL, Assembly	Autocoder
RE-ENTRANT COMPILERS & ASSEMBLERS	Yes		Yes	Yes	
QUEUING METHODS	Elapsed time, priority of commands	Round-robin		First in-First out within 3 queues: consoles I/O, computing, other I/O	Round-robin
MEMORY PROTECT TECHNIQUE	Software with complete memory swapping	Hardware and software	Interpretive execution	Paging and privileged instructions	Software
DATA FILE PROTECT TECHNIQUE			User code, security keys, program name	Passwords and control characters	Lock words
NO. OF SIMULTANEOUS USERS	40	40	50	60	40
USER PRIORITIES ASSIGNED	No	No	No	No	No
RESPONSE TIME (at 80-100% system usage)		2 to 3 sec.		3 to 5 sec.	
CURRENT USER LOCATIONS (from CPU)					
Under 1 mile				0%	5%
1 to 20 miles				0%	85%
20 to 100 miles				0%	5%
Over 100 miles				100%	5%
GENERAL APPLICATIONS Inventory					
Sales analysis	X				
Order entry		X			
Scheduling			X		
Personnel			X		
Financial	X				
Accounting		X			
Simulation studies	X		X	X	
Engineering calculations	X		X	X	
Program debugging	X		X	X	
Scientific	X		X	X	
Educational	X		X	X	
Test editing		X			X
Typesetting					X
COSTS					
Line connection time	Basic charge		Charge for line time only	\$20/hour (5 hour/month/min.)	\$5/hour
CPU usage time	of		None	None	
Storage per month	\$350/month		None	First 60K bytes free, \$3/6K additional bytes	\$50/100K char.

and allow it to maximize throughput of a computational nature. The GE Data Net 30, for example, is an I/O processor used in conjunction with the GE 235 central processor, and it handles all incoming and outgoing messages. The GE Data Net 30 is a computer in itself, with 16K words of memory, and as such is able to improve the system response time by gathering all the messages coming in from the terminals, sorting and storing them according to the proper user, performing the necessary edit-

ing, and signalling whenever inputs are ready for the central processor. During this time period, the central processor has been able to execute some other user's program.

Other small computers which may be used as I/O processors, or message concentrators, include the 12- to 16-bit machines such as the DATA/620A, PDP-8, ADVANCE 6130, DDP-516, Sigma 2, and SEL-810A. These machines are described in the section entitled "General-Purpose Digital Computers".

PROFESSIONAL SOCIETIES AND ASSOCIATIONS

The following groups maintain active committees, sponsor conferences, and provide guidance and standards for their respective members on matters related to computers and data processing.

Advertising Data Processing Ass'n. c/o Dan O'Neill McCann-Erickson 485 Lexington Ave. N.Y., N.Y. 10017	Association of Management Consultants, Inc. Don C. Latella, Pres. 1400 Architects Bldg. Phila., Pa. 19103
American Ass'n. for the Advancement of Science (AAAS) Dr. Dael Wolfle, Ex. Officer 1515 Mass. Ave., N.W. Wash., D.C. 20005	Business Equipment Mfrs. Ass'n. (BEMA) Harry C. Anderson, Pres. Data Processing Group 235 E. 42nd St. N.Y., N.Y. 10017
American Bankers Association Dale L. Reistad, Director 90 Park Ave. N.Y., N.Y.	Computer Personnel Research Group (CPRG) Robert A. Dickmann, Chairman The John Hopkins Univ. Applied Physics Lab. 8621 Georgia Ave. Silver Spring, Md.
American Documentation Institute (ADI) James E. Bryan, Exec. Dir. 2000 P Street, N.W. Washington, D.C. 20036	Data Processing Management Ass'n. (DPMA) R. Calvin Elliott, Exec. Dir. 505 Busse Highway Park Ridge, Ill. 60068
American Fed. of Information Processing Soc. (AFIPS) H.G. Asmus, Exec. Sec. 345 E. 47th St. N.Y., N.Y. 10017	Data Processing Supplies Ass'n. G.J. Parisi, Exec. Dir. 211 E. 43rd St. N.Y., N.Y. 10017
American Institute of Management Jackson Martindell, Pres. 125 E. 38th St. N.Y., N.Y. 10016	Inst. of Electrical & Electronics Eng., Inc. (IEEE) Donald G. Fink, Gen'l Mgr. 345 E. 47th St. N.Y., N.Y. 10017
American Management Association (AMA) Lewis Abrams, Div. Mgr., Adm. Services Div. 135 W. 50th St. N.Y., N.Y. 10020	Institute of Management Sciences, The (TIMS) Harold H. Cauvet, Exec. Dir. Box 273 Pleasantville, N.Y. 10570
American Marketing Association Earl G. Johnson, Exec. Dir. 230 N. Michigan Ave. Chicago, Ill. 60601	Instrument Society of America (ISA) Herbert S. Kindler, Exec. Dir. 530 William Penn Pl. Pittsburgh, Pa. 15219
American Mathematical Society Gordon L. Walker, Exec. Dir. Box 6248 Providence, R.I. 02904	Internat'l. Fed. for Information Processing (IFIP) (Refer above to AFIPS)
American Records Management Ass'n. (ARMA) Eunice M. Thompson, Pres. 738 Builders Exchange Minn., Minn. 55402	National Business Forms Association (NBFA) Meredith R. Smith, Jr., Exec. Dir. Room 536, Federal Bldg. 1522 K St., N.W. Wash., D.C. 20005
American Society for Engineering Education W. Leighton Collins, Exec. Sec. 1346 Conn. Ave., N.W. Wash., D.C. 20036	Simulation Councils, Inc. (SCI) John McLeod, Editor P.O. Box 2228 La Jolla, Cal. 92038
Association for Computing Machinery (ACM) Mrs. Irene Hollister, Exec. Sec. 211 E. 43rd St. N.Y., N.Y. 10017	Society for Automation in Business Education E. Dana Gibson, Pres. San Diego State College San Diego, Cal. 92115
Ass'n. for Educational Data Systems (AEDS) Jay Fast, Exec. Sec. 1201 16th St. N.W. Wash., D.C. 20202	Society for Information Display Dr. H.R. Luxenberg, Exec. Sec. 10027 Kester Ave. Sepulveda, Cal. 91343
Association for Symbolic Logic Theodore Hailperin, Sec. P.O. Box 6248 Providence, R.I. 02904	Systems and Procedures Ass'n. (SPA) Richard L. Irwin, Exec. Dir. 24587 Bagley Rd. Cleveland, Ohio 44138
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Ass'n. of Data Proc. Service Organizations (ADAPSO) W.H. Evans, Exec. V.P. 947 Old York Rd. Abington, Pa. 19001	Textile Data Processing Association Samuel R. McGuire, Chairman P.O. Drawer 21207 Greensboro, N.C. 27420
	United States of America Standards Institute Donald L. Peyton, Managing Dir. 10 E. 40th St. N.Y., N.Y. 10016

MAJOR INDUSTRY CONFERENCES AND EXHIBITS

May 1967-May 1968

1967

CONFERENCE

May 8-10

Information Retrieval Equipment Show
Washington Hilton Hotel • Washington, D.C.

May 15-17

Power Industry Computer Application Conference
Sheraton-Chicago Hotel • Chicago, Ill.

May 16-18

National Telemetering Conference
San Francisco Hilton Hotel • San Francisco, Cal.

June 20-23

1967 International Data Processing Conference and Business Exposition
War Memorial Auditorium • Boston, Mass.

June 26-27

5th Annual Computer Personnel Research Conference
University of Maryland • College Park, Md.

Aug. 22-25

Western Electronic Show and Convention (WESCON)
Cow Palace • San Francisco, Cal.

Aug. 29-31

20th Anniversary Conference Assoc. for Computer Machinery
Sheraton-Park Hotel • Washington, D.C.

Sept. 11-14

22nd Annual ISA Instrument-Automation Conference & Exhibit
International Amphitheatre • Chicago, Ill.

Oct. 1-4

International Systems Meeting
Cobol Hall • Detroit, Mich.

Oct. 23-27

9th Annual Business Equipment Exposition and Conference
New York Coliseum • New York, N.Y.

Oct. 24-27

12th Annual Conference American Records Management Assoc.
Hotel Roosevelt • New York, N.Y.

Nov. 14-16

1967 Fall Joint Computer Conference
Anaheim Convention Hall • Anaheim, Cal.

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1968

Feb. 14-16

International Solid-State Circuits Conference, University of Penn.
Sheraton Hotel • Philadelphia, Pa.

March 4-8

14th Annual Data Processing Conference
Americana Hotel • New York, N.Y.

March 25-28

IEEE International Convention and Exhibition
New York Coliseum • New York, N.Y.

April 30 - May 2

1968 Spring Joint Computer Conference
Convention Hall • Atlantic City, N.J.

Lewis Winner

152 W. 42nd St.
New York, N.Y. 10036

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135 W. 50th St. • New York, N.Y. 10020

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IEEE
72 W. 45th St. • New York, N.Y.

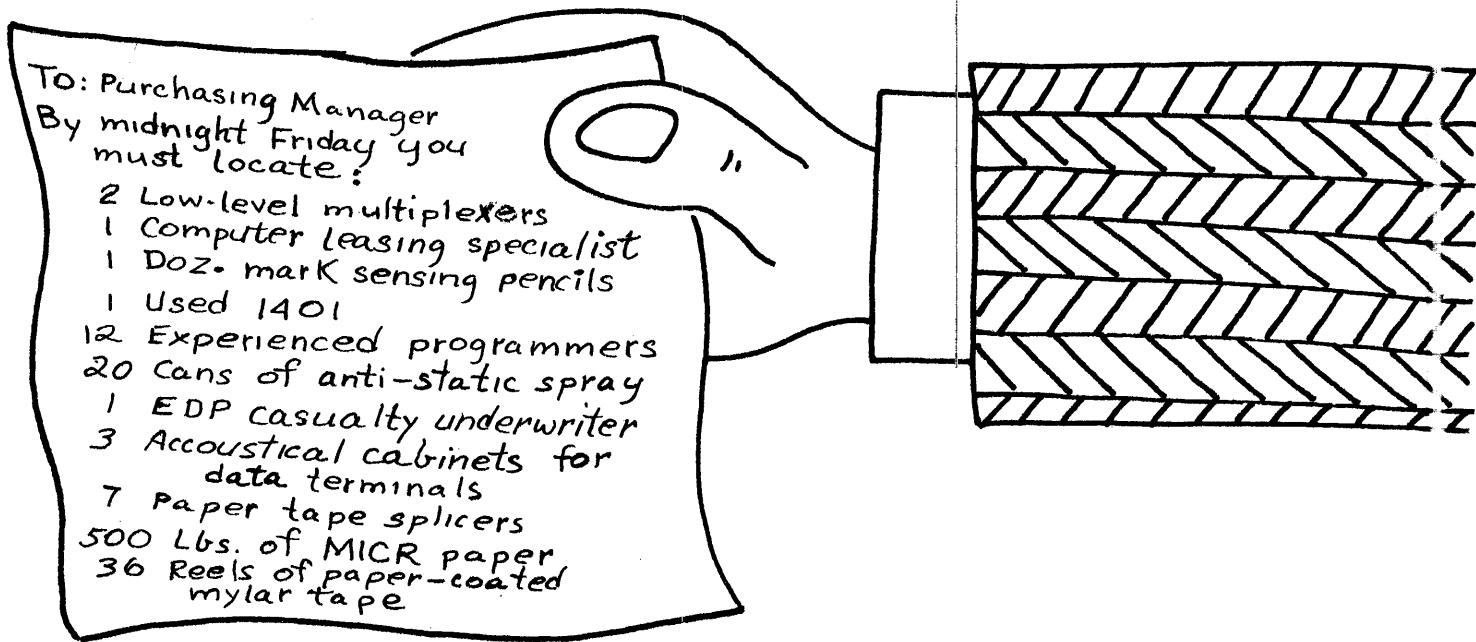
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