SYMPOSIUM: COMPUTER SYSTEMS AND APPLICATIONS IN THE OIL AND FAT INDUSTRY

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Introduction to Computers and Their Development[1]

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ABSTRACT

A data processing system can be a calculator, a bookkeeping machine, or a computer. Computers are based upon these five basic elements: a control unit, an arithmetic unit, memory unit, input unit, and output unit. Historically, first generation systems were physically large, able to be programmed only by bit manipulation machine language, very slow, and required extensive air conditioning and atmospheric control. Second generation computers saw the transition from electronic tubes to transistorized circuits speeding up internal processing. High levels compilers and assemblers were introduced, enabling programs to be written on a one-for-one assembly language basis, or on a two-to-one, three-to-one or more basis by using a compiler. Third generation systems saw significant improvements in utilization of microminiaturized circuits and interrupt handling that permitted development of complex operating systems including extensive progress in the area of time sharing and communications uses. Additional computers, first introduced in 1960, are the minicomputers. These minicomputers usually function in a dedicated environment and have many characteristics originally found in the third generation systems as well as many unique qualities of their own. Characteristics that categorize a computer as being a "mini" include purchase price of less than $25,000 at introduction, a memory size of 4000 bytes or more, minimal system configuration, and, usually, outright purchase. Minicomputer manufacturers are finding a large market for their product with dedicated applications and the original equipment manufacturer. The minicomputer may be the basis for still another generation of computers.

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INTRODUCTION

This paper discusses the principal elements of a data processing system, the stored program, the concept of programming, types of systems applications, and the more important terms being used today. It concludes with a discussion of minicomputers, which have become a significant aid in scientific research and process control.

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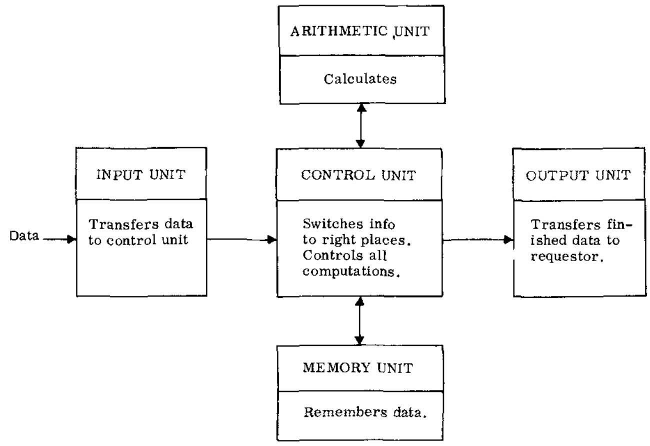

FIG. 1. Principal elements of a data processing system.

PRINCIPAL ELEMENTS OF A SYSTEM

A data processing system is not some mysterious piece of equipment that operates by itself; rather it is a collection of at least five elements which together create a system (Fig. 1). These basic elements are: (a) the input unit, used to enter data into the system; (b) the memory unit, the main storage area for data that is to be processed within the system; (c) the control unit, the "brain," because it controls and directs the functions of the other four elements of the system; (d) the arithmetic unit, performs basic arithmetic functions such as additions, subtraction, multiplication and division; and (e) the output unit, provides access to the results of processing.

Although a data processing system is usually a computer or computing system, it can also be a desk calculator or a bookkeeping machine. A computing system contains both input and output devices, such as the following: card reader (punched), tape reader (paper), tape reader (magnetic) input or output, disc (random access) input or output, drum (random access) input or output (two types, fixed or moveable head), video display terminal, teletypewriter (console), printer, card punch (output only), and paper tape punch (output only).

The first unit in our model system is the input unit, which transfers human language to the control unit. It does not necessarily translate human language to machine language. If translation does not occur within the input unit, then the control unit must perform this function.

The next unit is the memory unit. This area of the computing system is used to store three types of information: the commands to be executed, the information to be processed, and the intermediate and final results of the operation. Intermediate results are those obtained during calculations or data manipulation, and final results are those intended for the appropriate output devices. The third unit is the control unit, which controls all operations of the system, interprets orders from the programmer, and transfers information between all of the other units. The programmer provides the controls he wishes via a console, control cards, or the operating system.

The arithmetic unit performs all calculations involving addition, subtraction, multiplication and division. These operations can be decimal computations, which are used in a general commercial environment, or floating-point calculations, which are used in a scientific environment.

The final unit in our model system is the output unit, which transfers the results of calculations or data manipulations from the memory unit to another device where it is put into a format for final use. The high speed printer produces readily usable data in a hard and readable form and is the most frequently used output device. Other output devices such as magnetic tape, magnetic disc, punched card or punched tape, and magnetic drum do not deal with data immediately usable formats. Data output to these devices must ultimately be converted to a readable form such as printing or microfilm if they are to be used away from the computer.

The central processor almost always contains the three basic units, i.e., the memory unit, the arithmetic unit and the control unit. Input and output units can be combined in many ways and may be incorporated into a single device. In combining the two units, a small computer may be used as an input-output device to a large scale remotely located computing system, e.g., the Univac 1004 connected by communications lines to a Univac 1108. An example on a smaller scale is the operator's console, in which a remote video display terminal is used as both an input and output device. Another device used remotely for both input and output is the Univac DCT 2000, which can read and punch cards and then print at a fairly high speed.

STORED PROGRAMS

Having examined the basic elements of a data processing system, we must consider the stored program that makes the system function. A program is a set of sequential instructions which directs the data processing system to execute a specific task or process. Programs generally reside in memory (the storage area of the central processor) and can be executed whenever instructed to do so. A program may also be maintained out of the storage area, but memory is more convenient, since most instructions are repeated frequently and must be accessed quickly; programmed input devices are slower than the computer, itself.

A stored program originates with a programmer who writes the program in the language compatible with his system. Examples of the languages conventionally supported by most medium to large scale computers are Cobol (which is used for general business processing), Fortran (which is used for scientific calculations) and assembly language (which is usually unique to the particular system being used).

A program is nothing more than a preordered set of instructions which directs the system to perform a specific task or process. It is an integral part of the entire system complex and should be considered from a conceptual point of view. Figure 2 shows the logical sequence of a hypothetical program, with decisions and alternatives that must be made at each decision point. Starting at the far left is the instruction to set the alarm before retiring. The next action is to sleep. In the morning the alarm rings and awakens the sleeper. After turning off the alarm, he attempts to awaken his wife. If successful, he gets out of bed; if not successful he repeats shaking the wife three times before getting up. The program continues to its end, with various types of decisions at each juncture.

DATA PROCESSING CATEGORIES

Data processing systems may be categorized according to the major types of devices used: punched card, punched paper tape, magnetic tape, random access, time sharing, and communications. They can also be classified by application, as follows: batch processing, on line (communications), time sharing, combinations of the above, and dedicated (process control).

A batch processing system can be either card, paper tape, magnetic tape, or random access. The distinguishing characteristic is that all functions in a batch processing system are performed sequentially. Within any program many decisions must be made and tasks performed; it is the sequential execution of these events that distinguishes batch processing. In a random access application all functions are performed on a purely random basis. The difference between a random access system and a batch processing system in a typical master file update is that in a batch type system, all files would be passed sequentially and updated if they were active during the particular update. In a random access system, however, only those files having activity and requiring updating would be selected and processed.

In an on line communications system, which generally functions in a random access environment, only the master file record requiring action is accessed. A typical communications system is inquiry response, which is most notably used in inventory control systems, and reservation systems for airlines and hotels. Communications systems are also used for data collection and message switching, such as the rerouting of specified messages in a communications network.

In time sharing applications the total available time is divided among the individuals (terminals) utilizing the system. A time sharing system generally has many remote terminals, with a programmer at each one. In effect, the user has the system dedicated to himself for his particular program. Time sharing systems are typically used for engineering design calculations and pure research calculations. In this use of time sharing systems, conversational languages permit the programmer to compile a program one statement at a time. Time sharing is popular because it is convenient, i.e., the terminal can be placed in or near the user's office. Moreover, many people can use a time sharing system simultaneously at different terminals.

EVOLUTION OF COMPUTERS

Having described a model computer, its applications and structure, the next topic is the historical development of computers. In the first generation computers, the systems were large. Often they filled an entire room. They could be programmed only by bit manipulation machine language, were very slow, and required extensive air conditioning and atmospheric control.

Second generation computers made the transition from vacuum tubes to transistorized circuits. This improved internal processing speeds and reduced the size and heat of the equipment. High level compilers and assemblers were introduced, eliminating the need for intricate programming in machine language. The programmer was free to write programs using statements applicable to the language being used.

Third generation systems evolved from the introduction of microminiaturized circuits and interrupt handling that permitted development of complex operating systems. This enhancement further removed the programmer from direct contact with the computer. Now he had the facility to write programs in assembly language or compiler language. He no longer had to worry about many systems interface tasks, i.e., recognizing and handling I/O functions, due to the complex multilevel interrupt schemes. Third generation systems made extensive progress in the area of time sharing and communications uses of computer systems.

ARRIVAL OF MINICOMPUTERS

Since third generation systems were first introduced, everyone has been trying to determine what the fourth generation will bring. I cannot say that the minicomputer is the fourth generation system, but the day of the Mail-Order Computer has arrived. The 1969 Christmas catalog of Neiman-Marcus advertised a minicomputer for $10,600. This is humorous perhaps, but only because the sales

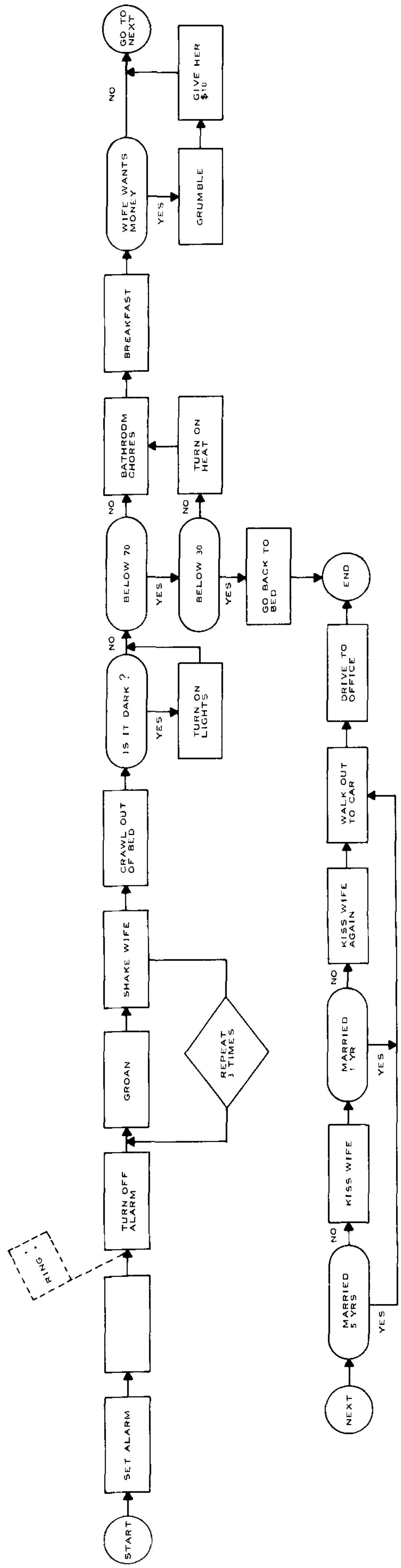

FIG. 2. How to get up in the morning.

TABLE I

Minicomputer Characteristics

Characteristics	Features Available		
	Minimum	Average	Maximum
Memory			
Word length, bits	8	8 or 16	18
Size, words	1024 to 4096	4096 to 32,768	1024 to 65,536
Increment size, words	1024	4096	8192
Cycle rate, kHz	125	571 to 1000	2000
(cycle time, μsec)	(8)	(1.0 to 1.75)	(0.5)
Parity check	No	Optional	Standard
Memory protect	No	Optional	Standard
Direct addressing, words	256	256 to 4096	All of core
Indirect addressing, type	No	Single-multilevel	Multilevel
Central processor			
General purpose registers	1	1, 2, 3, 4	128
Index registers	0	1	15
Hardware multiply-divide	No	Optional	Standard
Immediate instructions	No	Half yes-half no	Yes
Double word instructions	No	Over half do; rest to not	Yes
Byte processing	No	Half yes-half no	Yes
Input output			
Programmed I/O channel	1	1	1
I/O word size, bits	8	8/16	18
Priority interrupt lines	1	1 standard, up to 64 optional	2 standard, up to 256 optional
Direct memory access	No	Optional	Optional
I/O maximum transfer rate (DMA) words/sec	125,000	400,000 to 600,000	1,000,000
Other features			
Real time clock	No	Optional	Standard
Power fail-restart	Optional	Optional	Standard
Largest disc, megabits	No	2.1 to 9.0	183.6
Assembler	Yes	Yes	Yes
Compiler	No	Basic Fortran	Basic Fortran, Standard Fortran, Algol
Operating system	No	No	Real time, foreground-background
Purchase price			
Computer with 8K words of core and Teletype Model ASR 33	\$8200[a]	\$12K to \$15K[a]	\$24K[a]

[a]Price bears no direct relationship to the features listed in the column because one particular system does not have all of the features listed. Also, "8K words of core" sometimes refers to bytes and sometimes to 16 bit words.

technique is unique and the ad may be a bit premature. However, today's minicomputers are significant because they can handle scientific calculations and process control applicants economically and without large capital investments.

The question is "Why is a minicomputer a mini?" Although it was introduced in 1960, it was not called a minicomputer. I suggest that the name "mini" for these low cost small computers evolved from the popularity of the word "mini" as used in retail merchandising, particularly the clothing industry.

A minicomputer can generally be classified as a low cost, general purpose computer with the following characteristics: purchase price at introduction is less than \$25K; memory size is usually 4K words or larger; the system consists of a central processor unit and one input-output device (usually a teletypewriter or similar console device); software support includes only assembly language, Fortran, and/or Fortran IV (sometimes conversational Fortran support is offered); and the minicomputer is purchased, not leased.

Before describing the hardware characteristics of minicomputers, the following specific terms must be defined:

PIO channel: party line or programmed input-output. All devices connect to I/O line and the program selects the active device via a device address; all devices must recognize some address. Program controls each data transfer.

Direct Memory Access (DMA) channel: devices connected to a PIO channel for initiation instructions. Once initiated, the device transfers data directly to memory via the DMA channel, with the device or the channel controlling the transfer of each data unit.

Priority interrupt systems: a logic network to alert the processor that an external device requires attention or that an event has occurred. The network also establishes the priority of each attention-getting signal in respect to all other signals and queues signals by priority. A true priority interrupt system alerts the processor of an interrupt signal and the signal's priority. Other priority interrupt systems alert the processor to an interrupt signal but the processor must perform tests to determine the signal's priority.

Interrupt line: a line that carries one or more interrupt signals to the processor. A true priority interrupt system has an interrupt line for each interrupt signal.

Interrupt level: a priority distinction the processor can make for an interrupt signal, either automatic or by the program.

Traps: internal interrupt signals indicating a problem internal to the processor, such as parity error or arithmetic overflow.

ROM: read only memory (firmware in other systems) used to store important programs that must not be altered or microinstructions to define the processor's instruction set.

Microinstructions: the basic operations that are combined to form the computer's instruction set.

Memory protect: a scheme whereby memory can be partitioned into two or more areas. Programs residing in one area, the protected area, have access to all the computer facilities, including all of memory. Programs residing outside the protected area of memory have limited access to the computer's facilities and to the protected memory area. The purpose of memory protect is to allow foreground-background processing with the assurance that foreground programs can always run without interference from background programs.

Foreground-background processing: foreground programs are the primary responsibility of the computer system, while background programs run only when no foreground program needs to run. Executive routines and real time programs are foreground routines; any program can be a background routine.

Real time processing: the processor executes programs in response to the occurrence of an external event. The interrupt system signals the processor the real time event has occurred.

Real time clock: a device that synchronizes the processor with the passage of time.

The characteristics of minicomputers are shown in Table I, a reproduction of a chart that was printed in the January 1970 issue of "Auerbach Standard EDP Reports" and was out of date one month later. With the rapid growth of the minicomputer industry, memory sizes now offered range up to eight million words in 4K increments. The minimum price for the Micro is \$3200. One system, which costs \$10,600, includes floating point hardware. The maximum price for another system exceeds \$100K; this system provides 24 bit words.

There are two types of memories in the minicomputer: one is conventional core memory; the other is ROM or read-only memory. Conventional core memory is a standard storage area with memory speeds that range from 600 nsec for a 24 bit word to 2 μsec for a 16 bit word.

With ROM, a user cannot write to memory; he can only read from it. Whatever is contained in the read-only memory is prewired by the manufacturer.

ROM is unique to the minicomputer in two different ways (a) one manufacturer permits a user to develop his own program and punch it on paper tape. The program is then wired into the ROM. This method significantly decreases program execution time. ROM is also less expensive than most conventional core memories. (b) A second manufacturer offers a number of different ROM modules that can be changed by maintenance personnel.

Central processors for minicomputers range in size from a unit that is small enough to fit in a refrigerator to units that are as large as conventional third generation central processing units. Minicomputer central processors differ from the more conventional processors in three ways: (a) general purpose registers vary from 1 to 128 (optionally) and average 4; (b) index registers are not usually included in minimum processors and are optional in larger processors—up to 15 index registers can be ordered; and (c) processing is generally bit-oriented, but about 50% of the minicomputer central processors have byte-oriented processing as an option.

The instruction sets in minicomputers are also mini or minimal and frequently do not include hardware multiply-divide or floating point hardware. Multiply-divide is usually optional on the basic minicomputer central processor and standard on the larger central processors. Floating-point hardware is optional on almost all central processors, and frequently costs more than the central processor. Instruction sets are usually divided into six functional classes:

1. Load and Store instructions, which transfer data between memory and registers.
2. Test and Jump instructions, which examine for equality or sign and program jumps to alternate paths.
3. Arithmetic and logic instructions, which are add, subtract, multiply, divide and convert.
4. Register transfer instructions, which provide for register to register movement while executing, incrementing or decrementing.
5. Shift, rotate and control instructions, which perform the right and left shifts and alter or set control bits.
6. The input-output instructions, which control data transfers between peripheral devices and memory in parallel or serially in blocks.

In addition to the basic instruction set, there are optional extended instruction sets. These include double precision arithmetic or list processing instructions and two-word instruction formats, which contain an operand code and modifier bits in the first word and a memory address or data in the second word. More and more minicomputer central processors provide double address instructions because of the speed restrictions associated with single address or data in the second word. More and more minicomputer central processors provide double address instructions because of the speed restrictions associated with single address instructions and single accumulator architecture.

Input-output features for current minicomputers fall into four basic categories:

1. Direct Memory Access (DMA) channel: this channel is the fastest way to transfer data to and from memory without altering resister contents.
2. Byte Transfer instruction: this feature permits 8 bit communication codes to be stored in compact form in 16- or 18-bit machines without special subroutines.
3. block transfer instruction: this command specifies the beginning and ending memory location for high-speed transfer of fixed-size data blocks.
4. Mask Transfer instruction: a mask is usually under program control and can sense the status of external switches or setting relays and solenoids.

Software provided with minicomputers is minimal. Assembly language is predominant while Fortran, Fortran IV, and in some cases conversational Fortran are also offered. Higher level languages are not often used because memory restrictions, high machine efficiency, and timing requirements dictate efficient programming obtainable only in assembly language. An operating system may also be offered; this is usually a real time executive-monitor, which provides four basic functions:

1. Controls I/O data transfers.
2. Processes interrupts.
3. Allocates and protects memory.
4. Controls program swapping between memory and a random access device such as a disc or drum.

Applications for minicomputers are numerous, but the most frequent uses are in scientific research and development and process control. The medical environment uses minicomputers for intensive care patient monitoring and the dispensing of drugs, using badges and badge readers. In the communications area minicomputers are used for message switching, communications processing and data collection.

In the process control environment, an example of the numerous applications is the textile industry; there one system uses sensing devices to monitor 1368 machines. It records such statistical data as breakdowns, frequency of stoppage, production totals and operator efficiency. A final major use of minicomputers is in the Original Equipment Manufacturer (OEM) market. Because it is frequently cheaper for a manufacturer to buy a minicomputer than to develop his own special purpose computer, he will purchase a minicomputer on an OEM basis and incorporate it into his system. For example, Philco Ford is using another company's device in an optical character reader being developed for mail sorting.

An EDP system is a powerful but expensive tool for processing business data or performing scientific calculations. Since management is investing large amounts of money in EDP, it should expect the maximum return. With the never-ending procession of product improvements and new developments, it is important to gain a basic understanding of various equipment programs and techniques. Particular attention should be given to minicomputers because they already represent competition to medium to large scale systems; competition that will grow!