The Engineer's Computer

RAYTHEON 250 DIGITAL COMPUTER

The advent of small, low-cost engineering and scientific computers has given the engineer a new tool. Although larger digital computers have played an important role in research and design, the cost has limited their use to the most extensive problems. Because of this, most engineers continue to solve many problems with slide rule and desk calculator. Using the small computer, the individual engineer has direct access to analyze the problem, program the computer and tabulate the answers.

The engineer with a problem to be solved on a digital computer no longer finds it necessary to explain the problem to the programmer, arrange to have machine time available and then wait for the results. Large computers require maximum use by skilled programmers to amortize their cost. The relatively inexpensive small computer can be immediately available to the engineer and adjacent to his desk. The engineer can be trained to use the computer effectively in a few hours. With experience, he will learn to use the computer to minimize manual computations and, ultimately, to reduce overall engineering time.

Minor errors no longer cause long delays. Program or computational errors may be ascertained quickly and corrected by observing the operation of the machine. Because the engineer is included in the computation loop, his ingenuity and experience may be used to aid the problem solution. The engineer may observe trends in the results, stop the program and rearrange data at will.

The small computer is not intended to replace larger ones, but in fact complements them. They may be used to solve problems that are not economical to program on the large machines. Small computers also may be used in conjunction with large computers. They can check out portions of large programs to evaluate programming techniques, ascertain the most economical programming methods as well as estimate the amount of time necessary to execute programs on large machines.

The use of small digital computers is ideally suited for design problems where repetitive or extensive calculations are necessary. The small computer is ideal in circuit, filter and worst-case design. The computers best lend themselves to applications where an engineer using a slide rule or calculator can solve the problem in several hours. With the small computer, the engineer can have a solution in a few minutes.

COMPUTER HARDWARE

Basically all digital computers have four functional parts. These parts are: input/output devices, a memory, an arithmetic section and a control section.

Through the input/output devices, the computer receives instructions and data and provides the answers that it produces. Computer instructions and data may be entered with a manual device: a typewriter or a separate keyboard having special designations. Magnetic tape, punched cards and punched tape are used for a more rapid entry. The method used is dictated by the ultimate use of the computer and often these devices are used to increase the memory of the computer. Cards and magnetic tape offer a convenient method of up-dating permanent storage. Paper tape is more convenient to use with the small computer, although most computers have parallel input channels available for use with more than one type of input equipment.

New price — $23,500 We give you 3856 words for $23,500

	Model	Monthly rental (dollars)	Outright sale (dollars)	Compatible auxiliary equipment	Memory type	Memory storage (words)	Word size (bits)	Software available I = Interpreter C = Compiler A = Assembler	Program system used	Programming time	Execution time per solution
Burroughs Corp. Second Ave. at Burroughs Detroit 32, Mich.	E103	900	28,400	Card Magnetic tape	Drum	220	Variable serial	None	Machine language	16 to 24 hr	60 sec
Control Data Corp. 8100 34th Ave. S. Minneapolis, Minn.	G15D	995 to 1530	22,500	Card Magnetic tape Graph plotter	Drum	2176	29	I, C, A	INTERCOM 500	0.5 hr	45 sec
	8090 control computer	Not available	45,500	Card Magnetic tape Graph plotter Line printer	Core	4096 expandable	12	I, C, A	FORTRAN	0.25 hr	12 sec
Digital Equipment Corp. Maynard, Mass.	PDP-5	900	27,000	Card Magnetic tape CRT display	Core	4096 expandable	12	I, C, A	FORTRAN 2	Variable	9 sec
General Precision, Inc. Commercial Computer Div. 101 E. Tujunga Ave. Burbank, Calif.	LGP21	Not available	21,500	Card Teletype	Disc	4096	32	I, C	Floating Pt. interpreter	0.5 hr	50 sec
	LGP30	1100	24,500	Card	Drum	4096	32	I, C, A	Floating Pt. interpreter	0.5 hr	17 sec
	RPC4000	1865	47,000	Card	Drum	8008	32	I, C, A	Floating Pt. interpreter	0.5 hr	5 sec
Pacific Data Systems 1058 E. First St. Santa Ana, Calif.	PDS1020	Variable	21,500	Parallel input/output channels for use with other manufacturers' equipment	Delay line	2048 expandable	17	I, A	Engineering interpreter	0.3 hr	30 sec
Packard Bell Computer 2700 S. Fairview Santa Ana, Calif.	PB250R-4	1300	33,300	Card Magnetic tape Recorder Data systems	Delay line	2320 expandable	21	I, C, A	CINCH	Less than 1 hr	1 sec
Scientific Data System 1649 17th St. Santa Monica, Calif.	SDS910	1740	51,000	Card Magnetic tape CRT display Line printer Graph plotter	Core	2048 expandable	24	C, A	FORTRAN 2	Less than 1 hr	4 sec

We're now Raytheon!

Look pay

TO *give the design engineer an indication of the availability and variety of small computers, EDN has surveyed the computer market and prepared this table.*

In listing the manufacturers, EDN placed a maximum limit of approximately $50,000 for outright sale.

EDN established minimum input/output devices to insure versatility. To enter variable data, a manual input device was required. In most machines, manual entry is made with an electric typewriter although a separate keyboard is used sometimes. Printed output also was required. All computers listed use an electric typewriter. Rapid entry of pre-prepared data or information precludes entering data manually. EDN required that one method of automatic information entry and retrieval be included in basic cost of computer. Output device was required to prepare and store data in a format suitable for re-entry in the computer. All computers listed use punched paper tape. Information is entered into the computer by a paper-tape punch and reader as a separate device or by units associated with the electric typewriter. It is with these devices that the software programs or pre-prepared data are entered. Using tape, a program can be prepared, used and then stored to eliminate duplication of effort when similar problems are encountered.

The chart lists some of the basic types of software used with these computers. Interpreter programs convert mathematical language into machine language. Often included in interpreters are subroutines that will perform square root, power and trigonometric functions with a single command. Interpreters generally create machine language to be used directly in a sequence of instructions in machine language. The assembler is a utility program that uses symbolic address notation in place of the machine-language addresses. A compiler is a programming system that accepts problem statements in a problem-oriented language and converts these statements to a language suitable for direct machine processing.

To give the design engineer an indication of the time required to solve problems using the digital computer, each manufacturer was asked to solve the RLC problem given in the example. Absolute values of impedance and phase angle were requested for 10 values of ω with component values held constant. The programming time typically varies with the individual, but only seconds were required to execute the calculations and print answers.

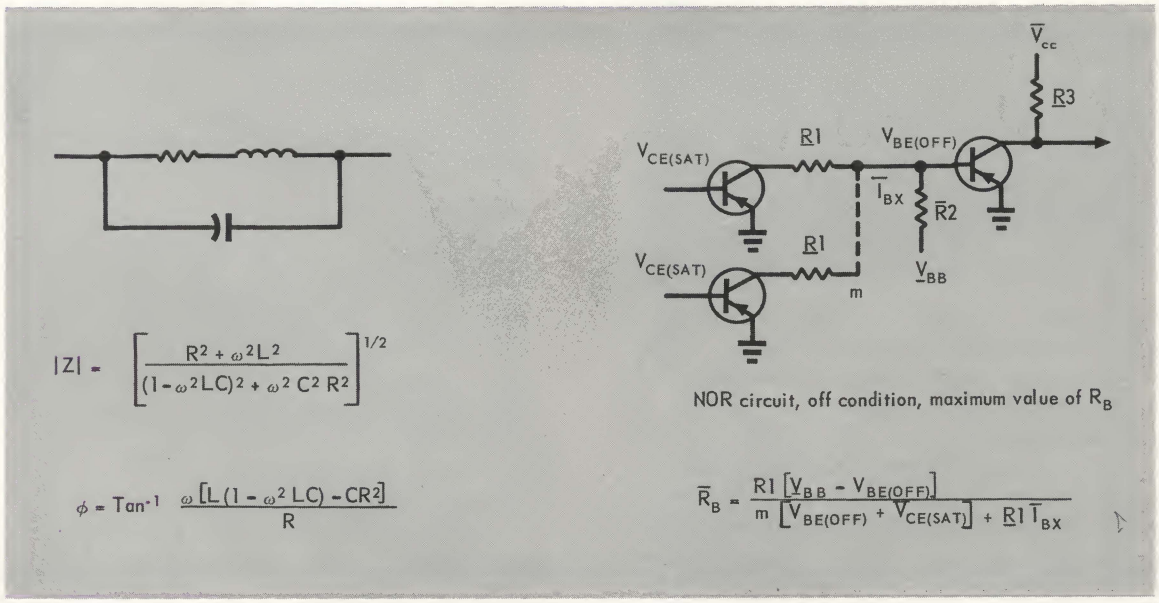
We now have Fortran II to speed up and simplify programming!

For printed output, the low-cost computer normally uses a typewriter and has some method of punching paper tape for a stored output. As with the input devices, many of the computers are compatible with other output devices such as card punches, magnetic tape, line printers, chart plotters and CRT display. The significant trade off is system complexity versus ease of use: the more complex the equipment, the further its engineer is removed from the computation loop.

The computer memory is used to store the instructions as well as data on which it operates. There are several types of computer memories available that vary in speed, size and cost. Four basic types of memory are used: drum, disc, delay line and core. The compromise is memory cost versus memory speed. The fastest and highest priced device is the core memory. Core memory has complete random access so that it requires no special programming to achieve maximum retrieval time. Also, the core has nonvolatile storage and information is not lost because of power failure. The high cost of the core memory results from the relatively complex system necessary to store and retrieve information.

On the other end of the scale, the slowest memory is the rotating magnetic drum. The rotating disc memory is slightly faster but the maximum storage is usually less than that of the drum. Because the read/write heads are located at fixed points around the rotating unit, special programming techniques are necessary to achieve maximum efficiency from the computer. In low-cost computers, this is not of great importance and inefficient programming will make only a few seconds difference in the computation time of most problems.

The delay-line memory is faster than the disc or drum memories and it is slower than the core memory. Recent advancements in delay-line technology have developed it into a reliable, low-cost memory system that is used in the several low-cost computers. It is, however, a volatile system. That is, information stored in the memory will be lost if power failure occurs. In practice, the problems of memory vol-

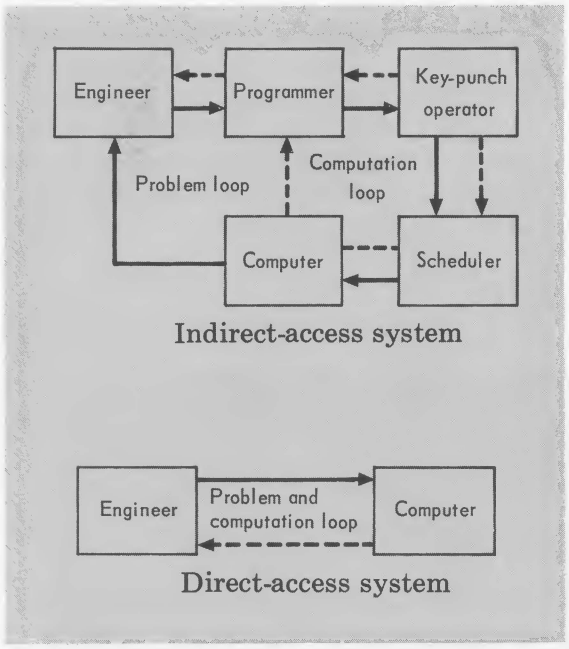


TYPICAL EXAMPLES *of problems that lend themselves to solution with low-cost digital computers. RLC circuit was used to obtain computation times shown in chart. Value of impedance and phase angle for 10 values of ω, passive components held constant, required only a few seconds after initial programming was done. Depending on the software available, solution involves a direct mathematical approach that is accomplished by setting up the basic equation of one value of ω. Multiple solutions are obtained by indexing the value of ω.*

A worst-case design may be accomplished easily on the small computer. In this case, a mathematical parallel to the breadboard treatment would be used. The equation would be set up to assign a maximum value for R_B. Parameters would be varied either in sets or for individual values to indicate the worst case.

atility are circumvented by supplying reserve power. A second method is to program the information stored in the memory on some permanent medium such as punched tape. Thus, when the information stored in the memory is lost, the computer may be programmed to reenter the information on the tape.

The arithmetic section of the computer consists of hardware that enables the computer to perform all necessary calculations. The control section or logic element of the computer coordinates the activities of the memory, input/output devices and of the arithmetic section. The complexity and cost of these sections are dictated by the input/output devices and the memory used.



SIMPLE FLOW CHART *graphically illustrates some of the advantages of the small computer. Solid lines indicate flow of information between elements in a large computer system. Dashed lines indicate the path followed when errors occur. Using indirect-access system, the engineer transmits the problem to the programmer who prepares the program. Key-punch operator codes program and scheduler assigns appropriate amount of machine time. Program is executed by machine and results are sent back to engineer. Even minor errors often cause delays. If engineer has not prepared problem correctly, programmer must return it to engineer for clarification. Errors in programming, key-punch operation or scheduling cause the problem to be returned to the programmer. This further increases time to obtain results. Using a small computer, the engineer's direct knowledge of problem aids in problem solution. Errors introduced in machine are immediately apparent and easily rectified by the engineer. The actual computation time is increased, but elimination of transmittal time often decreases the time from problem to answer.*

COMPUTER SOFTWARE

Software is the program used to extend the capabilities of a general-purpose computer. It is with software that the engineer adapts the machine to solve particular problems. The programming techniques are called software to distinguish between machine functions that are built into the machine hardware. In its basic form, the computer offers maximum flexibility when programmed in machine language. Machine language is a basic code that is acceptable to the machine without further modification. To program a computer in machine language requires an intricate knowledge of the computer as well as a thorough knowledge of mathematics. Using only machine language, the computers generally perform addition, subtraction, multiplication and division. Other functions such as trigonometry, roots and powers are generated by using the four basic functions and mathematical techniques. It is through the use of software programs that the engineer communicates with the computer. The software programs convert a language familiar to the operator into the machine language acceptable by the computer. Some programs include subroutines that allow the operator to perform complex mathematical operations with a single command. Other types of programs code instructions, assign machine address locations and combine subroutines. Many software programs are written to solve specific engineering problems.

GLOSSARY

Rather than print an incomplete glossary, EDN refers interested persons to "Automatic Data Processing Glossary". This excellent 62-page booklet is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C. The price is $0.40.

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