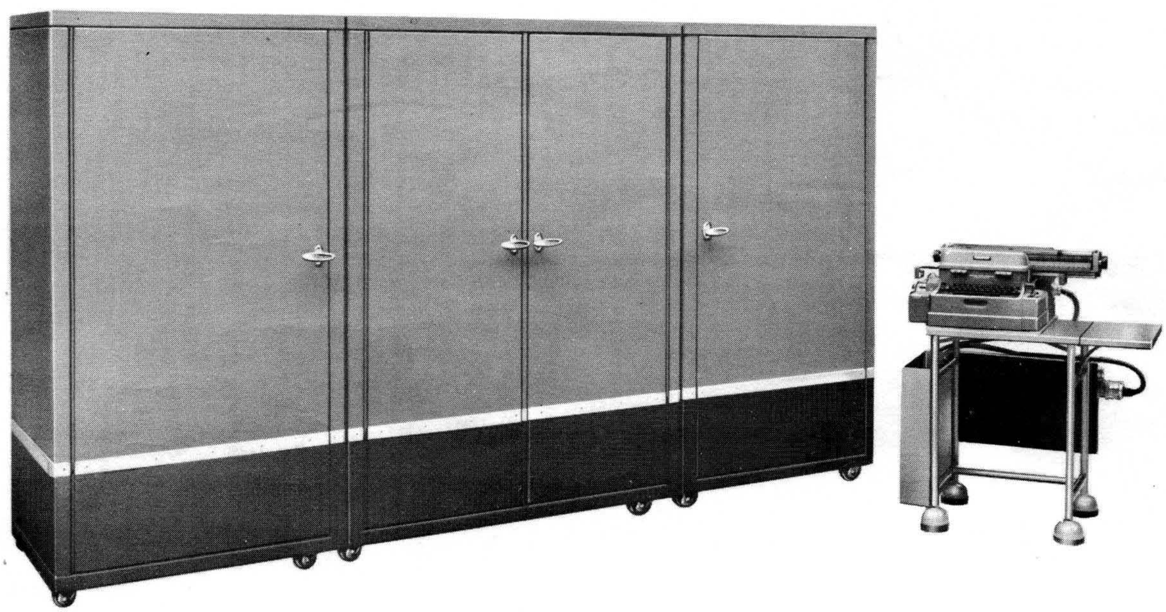
THE ALWAC

GENERAL PURPOSE DIGITAL COMPUTER



Logistics Research Inc.
141 South Pacific Ave.
Redondo Beach, Calif.

Logistics Research Inc.
General Purpose Computer
The ALWAC

GENERAL DESCRIPTION

The ALWAC is a general purpose digital computer of the internally programmed magnetic drum type. Designed primarily for use by small commercial and technical organizations having large computational requirements, this machine is operable without specially trained computer staffs. The designers of the ALWAC present the most advanced version of a low-priced, fully automatic computer available to date.

The ALWAC features a large capacity magnetic drum memory capable of permanently storing most of the standard routines that make up the major part of the computational work load of many engineering or accounting staffs. Electric typewriters with associated paper tape perforating and tape reading equipment are used as the basic input-output devices. Master programs containing numerical data to be operated on by these standard routines can be entered into the computer from the punched tape or manually via the keyboard. The final results can be printed out with form control, signs, decimal points, and alphabetical headings completely under the control of a permanently stored sequence of instructions. As many as ten electric typewriters can be attached to this machine at various remote locations and the computer will automatically scan these units for waiting problems whenever it has been cleared from a given problem.

Data reduction, trajectory studies, solutions of simultaneous equations, matrix algebra and matrix inversion, Monte Carlo methods, and partial differential equations are a few of the technical problems which this computer can readily handle. In commercial applications, payrolls can be automatically computed and pay checks printed; amortization schedules can be obtained in final printed form; statistical analyses, cost accounting, and production control problems can be solved; and many problems that can be expressed in numerical form can be handled in a single computer installation. A library of standard routines will be available to organizations using this computer.

The ALWAC is a serial, binary computer with automatic conversion from decimal-to-binary and binary-to-decimal during input and output accomplished by an internally programmed routine. Recirculating working channels and arithmetic registers permit high computational rates as a result of the low access times in these stores. The extensive repertoire of commands in conjunction with the unique method of addressing makes it relatively simple to program new problems for the ALWAC.

MEMORY CAPACITY

The magnetic drum memory consists of a 2048 word main storage, a 64 word working storage, 4 arithmetical registers, and the clock and timing channels. The words in the main storage are arranged into 64 channels containing 32 words each. Each word consists of a 32 binary bit number (equivalent to about 9.5 decimal digits) with a sign digit and two check digits. Additional 2048 word drums can be attached when greater storage capacity is required.

Each word space in the memory is divided into four order spaces, called syllables, and each syllable is capable of storing a command or order which the computer will carry out. This compact method of storage for instructions is made possible by a unique system for specifying addresses for the computer. Most of the commands that the machine will carry out do not require addresses; therefore, a great deal of storage space is saved by having addresses only when they are needed. The machine proceeds from one syllable to the next in a standard sequence in looking for its orders. When it finds an order which requires an address, it looks at the next syllable in the normal sequence and interprets the number located there as the address. Then it will look in the next space after that for its next order.

MEMORY SYSTEM

All arithmetical operations are performed in the four single word recirculating registers designated as the A, B, D, and E registers. Most of the commands are carried out on the number in the A register, which also serves as an accumulator for the results of additions and subtractions. The B register is combined with the A register to contain a double length product or dividend. The two factors to be multiplied are held in the D and E registers. In division, the divisor is held in the D register, and the quotient in the E register. Automatic and programmed exchanges of numbers which occur between these registers are described in detail in the list of commands.

The working storage consists of two channels of information, each recirculated between two tracks by read-write circuitry on opposite sides of the drum. As each digit space in a working channel appears under the read head for that track, its contents are amplified and transmitted to the write head on the adjacent channel.

The computer also selects its commands from the information in the working channels. Any channel containing numbers or commands in the main memory is recopied into one of the working channels before any operations are performed with the stored contents. This procedure provides many advantages in the application of the computer. Many subroutines such as the square root, sine, logarithm, or exponential computing subroutines can be stored in the main memory and recopied into a working channel when needed. Control is temporarily shifted to the subroutine, but a skip order is inserted at the end of the subroutine to send control back to the main routine when the subroutine is completed. Since numbers or commands which may be altered during the course of the computation remain unchanged in the main memory, it is not necessary to restore sequences of instructions or numbers for subsequent use of the same routine.

COMPUTING SPEED

The standard spacing of orders and the use of multiple reading heads in the recirculating stores give the computer high computing rates. Most of the orders can be completed in the time that it takes for one word to pass under the read heads, which is 1/960 second or approximately one millisecond. Therefore, the normal spacing of orders is in a syllable in each alternate word. With optimum coding, numbers in the working storage can be added or subtracted in the accumulator at the rate of 240 per second; and with random access coding, at an average rate of 120 per second. The multiplication or division of two numbers in the arithmetic registers is completed in 34 milliseconds.

RELIABILITY

The fundamental design philosophy followed in developing the ALWAC was to obtain a computer that would be entirely reliable in its operation at all times with no possibility of losing any information once it had been stored in the main memory. These aims have been accomplished by very conservative use of the operating ranges of all electrical components, a simplified checking routine for detecting any electrical components which may become marginal, and automatic self-checking features in various critical computing sequences.

Operating with a clock pulse rate of only 67 KC and trigger voltage levels of 0 and +15, this computer uses only a small part of the rated capability of its crystal diodes and electronic tubes. As a further result of the low pulse rate, the dynamic response characteristics of the electronic circuitry is relatively non-critical; therefore, the normal drift in component characteristics will rarely affect the computing operations.

All electronic components are arranged into standardized plug-in units of limited variety to facilitate routine preventive maintenance checks and the replacement of marginal units. A test box for these plug-in units is installed as part of the computer, making it entirely practical to check all electrical components in the computing circuitry in less than one hour. This test box automatically gives each plug-in a static and dynamic check of all grid and bias voltage in excess of the normal operating range. Satisfactory operation of a unit is indicated by a green light on the test panel, whereas a red light indicates that the unit should be replaced.

Self-checking features in the computer will detect many of the coding or machine errors that might occur, such as the unforeseen overflow of the arithmetic registers, the receipt of a non-existent order, or the attempt to copy a working channel into the wrong channel of the main memory. Any of these errors will stop the computer and an alarm will be given. Indicator lights on the display panel will then show which type of error has occurred.

INPUT-OUTPUT

Information to be stored in the main memory is normally stored first on punched paper tape by typing the numbers and code letters in the proper sequence on an electric typewriter. A visual copy will be typed at the same time, which may be immediately compared with the coding sheet for typing errors. The information is then automatically transferred to magnetic drum storage by the electric typewriter tape reader. Information can also be entered manually directly from the typewriter keyboard.

Numbers to be entered in the computer are normally typed on the electric typewriter in decimal form with decimal point and sign. Conversion from decimal-to-binary and binary-to-decimal during read-in and read-out is automatically performed by a subroutine at approximately the maximum rate of the electric typewriter reading and writing speed of ten operations per second.

Automatic graph following and graph plotting equipment can also be provided as input and output equipment for this computer. One version of the automatic graph follower will handle a function of two variables. Families of curves on a single sheet may be used and the follower will automatically switch from one curve to another in response to commands from the computer and automatically transmit the ordinate reading to the computer storage.

PHYSICAL SPECIFICATIONS

The entire computer is installed in three cabinets finished in grey and black wrinkle and mounted on ball-bearing swivel casters. The cabinet containing the magnetic drum memory is 28" deep x 34" wide x 64" high and weighs approximately 380 pounds. The cabinet containing the power supply is the same size and weighs approximately 520 pounds. The cabinet containing the logical elements of the computer is 28" deep x 48" wide x 64" high and weighs approximately 500 pounds. The machine will operate from either a standard 110 or 220 volt, 60 cycle, single phase outlet and requires approximately 4 KW of power. The operation of internal fans provide adequate cooling of the computer at normal room temperature.

WARRANTY

A one-year guarantee is given on all parts and components against failures which occur as the result of normal usage of the computer. Scheduled maintenance service is included for a period of one year and special maintenance service will be provided during this period in the event a breakdown occurs which cannot be corrected by a routine check of the plug-in units by the customer.

INSTRUCTION CODE

The command list for the ALWAC is separated into four groups: orders which require no address; orders which are followed by the address of a word; and orders which are followed by the address of a channel. If the computer finds a blank order space in the normal sequence of commands, it will perform no operation and will proceed to the next order space in the sequence for its next instruction. Routines are most conveniently terminated by one of the Flexowriter input commands. Then if there is no code on the tape in the reader, the computer will halt all operations and wait until a coded tape is entered or an input is received from the keyboard. New data can then be entered for the computation routine in working storage, or the working storage can be cleared and the fill routine copied from the main memory to receive the next problem.

ORDERS WHICH DO NOT REQUIRE AN ADDRESS

COMMAND	CODE
1. NUMBER INPUT	t4

Copy from tape or keyboard into the four right hand digits in A the binary form of the decimal digit punched on tape. This order is used when entering numbers from the electric typewriter tape (or from the typewriter keyboard) to the computer.

2. LETTER INPUT — tc

Copy from tape or keyboard into the six right hand digits in A the binary form of the typewriter letter or symbol punched on tape. This order is used when storing alphabetical material, arithmetic symbols, or typing instructions such as tab control or carriage return.

3. SIGN INPUT — ts

Read the tape or keyboard for the sign code and make the sign of the number in A correspond.

4. NUMBER OUTPUT — s4

Transfer to tape or keyboard the last four binary digits to the right in A. This order is used to take numbers from the computer.

5. LETTER OUTPUT — sc

Transfer to tape or keyboard the last six binary digits to the right in A. This order is used to transmit alphabetical information, arithmetic symbols, or typing instructions such as tab control or carriage return to the electric typewriter.

6. SIGN OUTPUT — ss

Transmit to tape or keyboard the sign of the number in A.

7. CLEAR — yh

Change the number in A to zero and make the sign digit positive.

COMMAND	CODE
8. NEGATE	-r

Reverse the sign of the number in A and leave the number itself unchanged.

9\. ABSOLUTE VALUE — -p

Make the sign of the number in A positive.

10\. COMPLEMENT A — ka

Complement the number in A including the sign digit.

11\. SYLLABLE SHIFT — ar

Shift A right one syllable (8 binary digits). Digits leaving the right-hand end come back in the left-hand end. This command is useful in routines which modify themselves during the course of the computation.

12\. RIGHT SHIFT — jr

Shift A and B right one digit. That is, shift each digit in A and each digit in B right one position, the last digit to the right in A becomes the first digit to the left in B, the first digit to the left in A becomes zero, the last digit to the right in B is lost.

13\. LEFT SHIFT — jn

Shift A and B left one digit. That is, shift each digit in A and each digit in B left one position, the first digit to the left in B becomes the last digit to the right in A, the first digit to the left in A is lost and the last digit to the right in B becomes zero.

14\. COUNT DOWN AND ZERO TEST — yk

Subtract one from the absolute value of the number in A and turn the overflow on if the result is zero. This order is especially convenient for terminating a routine which repeats itself a preset number of times. A "conditional skip" order following this command can return control to the beginning of the routine until the count down yields a zero and the overflow is turned on.

15\. ACCUMULATIVE MULTIPLY — ax

Multiply the number in D by the number in E and store

COMMAND	CODE

the product in the combined A and B registers with the most significant part in A. The sign digits for both the A and B registers will have the correct sign of the product. The absolute value of any number stored in A is added to the product. The number stored in B is transferred to E and the factor originally stored in E is discarded.

16. DIVIDE — m-

Divide the double length number in AB by the number in D. The quotient will be stored in E, and the remainder is retained in A. If the quotient exceeds the capacity of the E register, the division will not be performed and the overflow will be turned on. If it is anticipated that the division might result in an overflow, this order could be followed by a conditional skip order, which would transfer control to a scale-down routine or to a print out routine (which would show the operator where the overflow occurred), or any other routine to meet the requirements of the problem. Any number stored in E will automatically shift to B during the division.

One useful application of this automatic transfer of a number between the E and B registers during division and multiplication is for retaining the factor to be "counted down" in reiterated routines.

17. COPY D IN A — lt

Write in A the number in D and leave D unchanged.

18. EXCHANGE — zz

Exchange the numbers in A and B.

19. EXCHANGE — zd

Exchange the numbers in A and D.

20. EXCHANGE — zv

Exchange the numbers in A and E.

21. EXCHANGE — va

Exchange the numbers in A and the specified word.

COMMAND	CODE
22. REVERSE OVERFLOW	-v

If the overflow is on, turn it off. If it is off, turn it on.

23. ZERO TEST — 1k

Turn the overflow on if the number in A is not zero. If the number is zero, do nothing to the overflow.

24. NEGATIVE TEST — 1n

If the sign of the number in A is negative, turn the overflow on; if the number is positive or zero, do nothing to the overflow.

ORDERS WHICH ARE FOLLOWED BY THE ADDRESS OF A SYLLABLE

25. COPY — xw

Copy a designated syllable from working storage into A. The syllable will occupy the same relative position in A that it occupied in its original word. It is not necessary that A be cleared previously. The other three syllables in A are left unchanged.

26. COPY — xa

Copy a syllable of A into a specified syllable. The syllable of A which is copied is that syllable which occupies the same relative position as the specified syllable.

27. CONDITIONAL SKIP — cs

If the overflow is on, take the next order from the specified syllable; otherwise, continue in the standard sequence of orders. This order turns the overflow off.

28. UNCONDITIONAL SKIP — pp

Take the next order from the specified syllable.

ORDERS WHICH ARE FOLLOWED BY THE ADDRESS OF A WORD

29. ADD — wa

COMMAND		CODE
	Add the number in the specified word to A. Leave answer stored in A. If capacity of A is exceeded, turn on overflow.	
30.	SUBTRACT	ws
	Subtract the number in the specified word from A. Leave answer stored in A. If capacity of A is exceeded, turn on overflow.	
31.	ADD AND NEGATE	w-
	Add the number in the specified word to A and change the sign of the sum. Leave answer stored in A. If the sum exceeds the capacity of A, turn on the overflow.	
32.	SUBTRACT AND NEGATE	ww
	Subtract the number in the specified word from A and change the sign of the answer. Leave answer stored in A. If capacity of A is exceeded, turn on overflow.	
	The four add and subtract orders above give all possible combinations of sums and differences between a number in A and any number in working storage. The numbers in the specified words are not changed in carrying out these orders.	
33.	EXTRACT	xl
	Leave a digit in A only where there is also a digit in the corresponding position in the specified word (logical multiplication). This order is useful in dealing with only parts of a word and permits breaking a word up into several numbers and then extracting them individually.	
34.	DOUBLE EXTRACT	hl
	Copy the specified word into A only in those digits in which there is a corresponding digit in D. Leave the rest of A alone. This order has many convenient uses in modifying orders, printing alphabetical information, and in dealing with parts of words.	
35.	COPY TO A	hh
	Copy the number in the specified word into A.	

COMMAND	CODE
36. COPY TO D	hd

Copy the number in the specified word into D.

37. COMPARISON TEST — uk

Turn the overflow on if the number in A is less than the number in the specified word. This order is usually used to determine when to terminate a reiterative summation of a series or a routine involving successive approximations.

ORDERS WHICH ARE FOLLOWED BY THE ADDRESS OF A CHANNEL

38. STORE CONTROL CHANNEL — rm

Copy the instructions and numbers which are now in the working storage channel from which the computer is taking its present order into the specified channel in the main memory. The computer will continue to take its orders from the normal sequence of locations.

39. STORE WORKING CHANNEL — rs

Copy the instructions and numbers which are now in the working storage channel from which the computer is not taking its present order into the specified channel in the main memory.

40. ACCESS CONTROL CHANNEL — qm

Copy the specified channel of the main memory into the working channel which is in control. The next order will be selected from this new channel at the syllable address which occurs in the normal sequence of order addresses.

41. ACCESS WORKING CHANNEL — qs

Copy the specified channel into the working channel which is not in control.

LOGISTICS RESEARCH INC.

141 S. PACIFIC AVENUE
REDONDO BEACH, CALIFORNIA

BRIEF SPECIFICATION OF THE ALWAC

MEMORY SYSTEM - Magnetic Drum

	CAPACITY	ACCESS TIME
Arithmetic Storage	4 words	1/960 second
Working Storage	64 words	1/960 to 8/960 second
Main Storage	2048 words	1/20 second

NUMBER SYSTEM - Serial, binary, absolute value with sign

ADDRESS SYSTEM - Zero address

(An address is substituted for a command in normal sequence of locations only when needed)

WORD SIZE - 32 binary digits plus 1 sign and 2 check digits (Equivalent to 9.5 decimal digits)

Words are divided into 4 syllables, each of which may contain a command, an address, or any 8 digit binary number.

OPERATING TIMES - Input: 10 decimal digits per second from punched tape or keyboard
Output: 10 decimal digits per second to tape or printer
Addition & Subtraction: 1/960 to 8/960 second
Multiplication & Division: 1/30 second

COMMANDS - 41 arithmetic, logical, and transfer commands

A, B, D, and E - arithmetic registers
W, S, or M - Word, syllable, or channel (write address number in next order space)

ARITHMETIC

Add W to A*
Add W to A and negate sum*
Subtract W from A*
Subtract W from A and negate difference
Multiply D and E, product in AB
Divide AB by D, quotient in E*

MODIFY ACCUMULATOR

Clear A
Reverse sign of A
Make A positive
Complement A
Shift A right one syllable
Shift A & B right one digit
Shift A & B left one digit
Logical product W·A in A

OVERFLOW

On if A is not zero*
On if A is less than zero*
On if A is less than W*
Subtract one from A; on if A now = 0*
Reverse *

COMMAND SKIP

Take S as next order
Take S as next order if overflow is on

COPY

W to A
W to D
D to A
S to A
A to S
Insert logical product W·D into A

WORD EXCHANGE

A & W
A & B
A & D
A & E

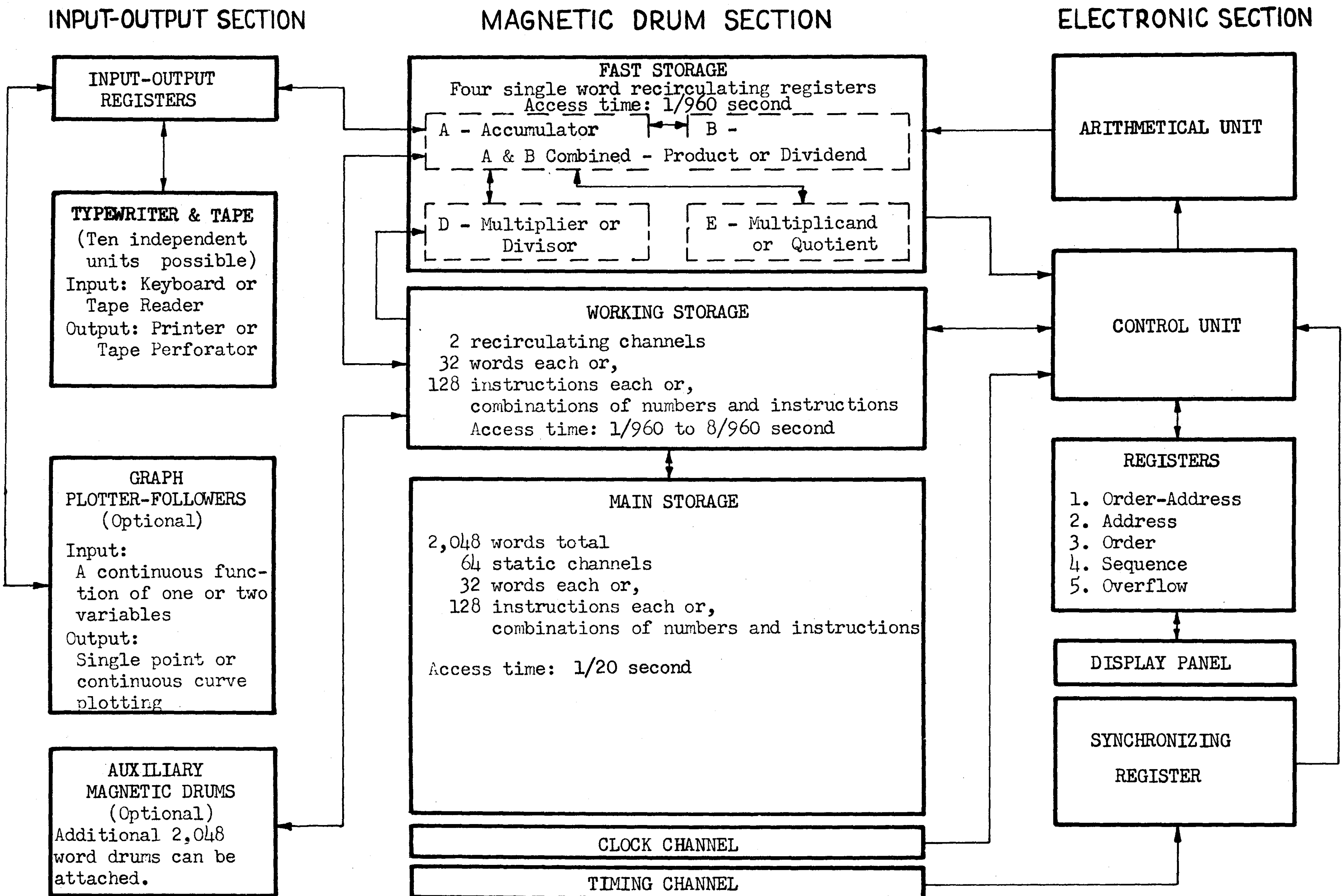
CHANNEL COPY

M to working storage
M to control position
Control channel to M
Working channel to M

TYPEWRITER & TAPE

Decimal digit to A
Alphabetical code to A
Sign code to A
Decimal digit from A
Alphabetical code from A
Sign code from A

* Orders which may turn on overflow



the "Alwac"

GENERAL PURPOSE digital COMPUTER